Sandia Annual Report 2001

Sandia National Laboratories

A Department of Energy National Laboratory

Perspectives on National Security

Sandia National Laboratories applies advanced science and engineering to detect, repel, and defeat national security threats. Our national security mission has grown from responding to the threat of the Cold War to countering a host of less well-defined threats—some nuclear, some not.

We develop technologies to sustain and modernize our nuclear arsenal, prevent the spread of weapons of mass destruction, protect our national infrastructures, defend our nation against threats such as terrorism, and ensure the stability of our nation's energy and water supplies. Our science and technology programs contribute significantly to the nation's effort to remain technologically superior—a key to national defense and America's economic well-being.

our people are our biggest asset

Left:
Mark Claudnic and
Davina Kwon discuss
a computer-aided
design model.

Above:
Darren Buie
takes voltage
readings from
a nuisance alarm
data system.

Right:
Marlene Brown
inspects a
photovoltaic
unit.

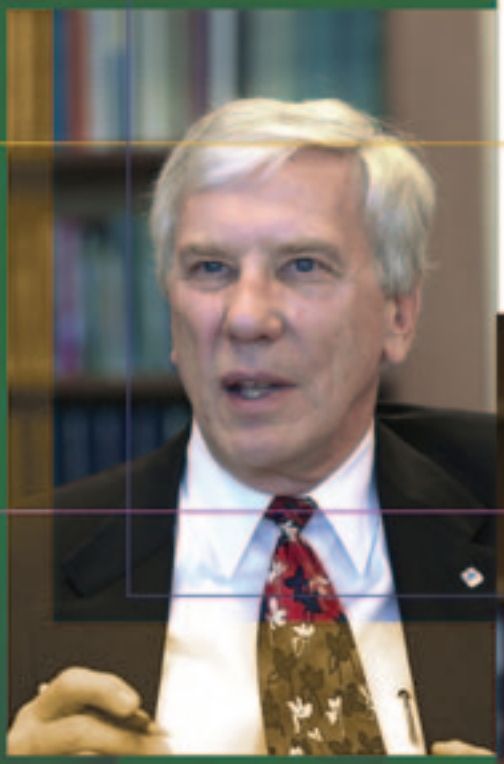
Sandia Annual Report 2001

From top: Solar water-detoxification system; Gary Rochau holds a large-scale cutaway model of what a magnetically insulated fission electrical cell might look like; electrical grid towers; minirobots.

CONTENTS

A Call for Exceptional Service

Sandia Stands Ready to Help Protect America



The horrifying attacks on our nation at the World Trade Center and the Pentagon, and the related airliner crash in southwestern Pennsylvania, have launched what President Bush called "the first war of the 21st century." The employees at Sandia National Laboratories and their families joined the nation in mourning the victims of these tragic events. We also accelerated our efforts in counterterrorism and security technologies, and we are working with a wartime commitment to do our part in this difficult and sustained national effort to eradicate terrorism.

As indicated in this year's Annual Report, Sandia has developed and continues to develop many technologies and systems that are designed to protect Americans and our interests at home and abroad. We are one of the nation's

foremost technical institutions, fulfilling missions for the National Nuclear Security Administration, the Department of Energy, and many other federal agencies. While Sandia's primary mission is to maintain the nation's nuclear weapons capability, including the development of new strategic options, a major aspect of our national security mission is to reduce the vulnerability of the United States to the proliferation, threat, or use of weapons of mass destruction.

America currently is on a war footing, but our goal is always to achieve peace. In that vein, the laboratories' executive leadership team this past year redefined our core vision—"Helping Our Nation Secure a Peaceful and Free World Through Technology." Our highest goal is to become the laboratory that the United States turns to first for technology solutions to the most challenging problems that threaten peace and freedom for our nation and the globe. This bold objective reinforces our continuing nuclear weapons responsibilities while recognizing that new and different challenges to national security are always emerging.

Sandia is doing its utmost to develop science and engineering solutions to national security problems. We do that with many of the best intellectual, scientific, and technical minds this nation has to offer. This year we began a five-year program to hire 2,500 new scientists, engineers, technologists, and administrative staff—a third of our current workforce. This new, highly educated, and diverse group of Sandians will build upon the achievements of the past in exciting and creative ways. Ultimately, we are only as good as our people and the tools they have to work with, and our people are among the nation's best and brightest.

We invite you to learn more on the following pages about the many ways Sandia's people are contributing to our national security and America's well-being.

C. Paul Robinson

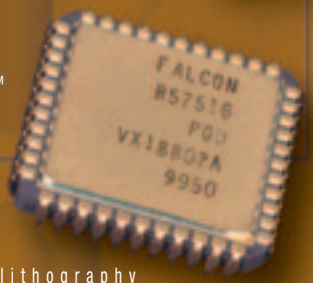
C. Paul Robinson,
President and Laboratories Director

Joan B Woodard

Joan Woodard,
Executive Vice President and Deputy Director

Science and Technology

Pursuing science with the mission in mind



Microcomponent manufactured with LIGA technology; Cold Spray™ deposition; magnetically levitated stage used in extreme ultraviolet lithography (EUVL) exposure tool; FALCON integrated circuits.

Sandia's missions require extraordinarily strong science and technology. We strive for and achieve advances that greatly improve performance—often by factors of 10, 100, or even 1,000. This year, for example, we witnessed a milestone in the extreme ultraviolet lithography (EUVL) project, which will lead to commercialization of new technology enabling microelectronic devices to follow Moore's Law for at least another decade, doubling the number of transistors every two years.

Much of our nation's economy has benefited from science and technology spurred by the demands of national security. A great deal of the nation's progress has resulted from an exceptional ability to conduct science with the mission in mind—to discover and engineer raw technology into overwhelmingly competitive products.

Building upon our traditional strengths in materials and computational sciences, we are making significant advances in microtechnologies/nanotechnologies, information technologies, and biotechnologies. These three areas will drive the Next Generation Economy. They support Sandia's strength in cognotechnology—our ability to assimilate massive amounts of computer-generated data into forms that people can understand. The human-machine interface—primarily, our interactions with computers of expanding capabilities—is the key to continuing our exponential advances in science and technology.

Al Romig,
Vice President
Science & Technology and Partnerships

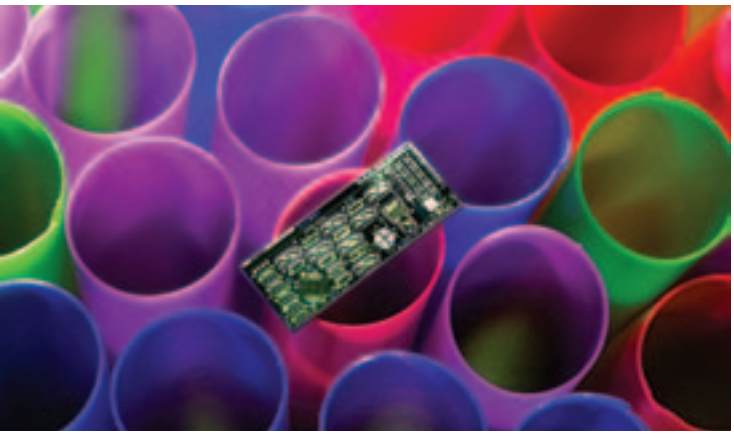
EXPLORING A FRONTIER A MILLION TIMES BEYOND THE PRESENT

Almost 60 years ago, a primer for young scientists beginning the Manhattan project proposed a bold frontier: unleashing the energy within atoms to create an explosive at least one million times more powerful than any chemical such as TNT. Nuclear fission, it proposed, was at least six orders of magnitude more powerful than the most explosive chemicals.

Today, the tradition of advancing by orders of magnitude continues in the science and technology programs at Sandia. The goals have changed dramatically, in line with the geopolitical restructuring of the past decade. Yet the frontier remains equally bold: how do we advance our control and application of nature's power? Over the past few years, and especially this most recent year, Sandia made advances based on the frontier of molecule-to-molecule and atom-to-atom interactions.

SMALLER IS BETTER—THE PROGRESSION FROM MICRO TO NANO

Our microsystems—microscopic, smart devices that integrate mechanical devices, sensors, and computing—can think, sense, act, and communicate. They are already



Sandia's prototype microdevice, resting atop 1/4-inch-diameter soda straws, contains inexpensive silicon microteeth that open and close like jaws to harmlessly trap red blood cells.

1,000 times smaller and 20,000 times more powerful than the first microsystems, and they are getting smaller, more powerful, more functional, and less expensive with every new application.

Microsystems will aid national security, with applications ranging from monitoring the health of our weapons, to safeguarding our sensitive materials and facilities, and gathering intelligence from space. Commercial microsystems are now appearing in everyday products such as improved airbags, digital projectors (using millions of microscopic mirrors), chemical detectors of greatly improved sensitivity, and robotic tools and prosthetic limbs with near-human dexterity and touch.

Sandia is a world leader in developing the growing new technology known as MEMS (MicroElectro-Mechanical Systems) or more simply, micromachines.

Throughout Sandia, we are just beginning to exploit the properties of machines that have so little mass that the laws of gravity and inertia are inconsequential. Much like microprocessors, we are building microsystems with semiconductor techniques, so that hundreds or thousands of them can be built on a single wafer. We are incorporating much more than traditional electronic components such as transistors, capacitors, and resistors. Using a five-level polycrystalline silicon surface micromachining process, Sandia is making basic tools like gears, pendulums, and levers, and then integrating them into complex machines such as transmissions and locks.

Although microscopic, these transmissions and locks are able to operate like their counterparts in automobiles, which are a million times larger. We are using our materials science expertise to create new semiconductor materials that are harder than diamonds, virtually frictionless, and more sensitive to chemical or biological agents than any previous system.

EUVL Holds Promise For Next-Generation Microchips

On January 25, 2001, a milestone was reached in the manufacture of advanced microchips. A prototype device for printing smaller features on more powerful microprocessors produced its first images using extreme ultraviolet lithography (EUVL), a technique chipmakers may use to make next-generation microchips.

EUVL uses a process similar to photographic printing, in which a wavelength an order of magnitude smaller than

Extreme ultraviolet lithography (EUVL) was developed to create future generations of smaller and faster microprocessors.

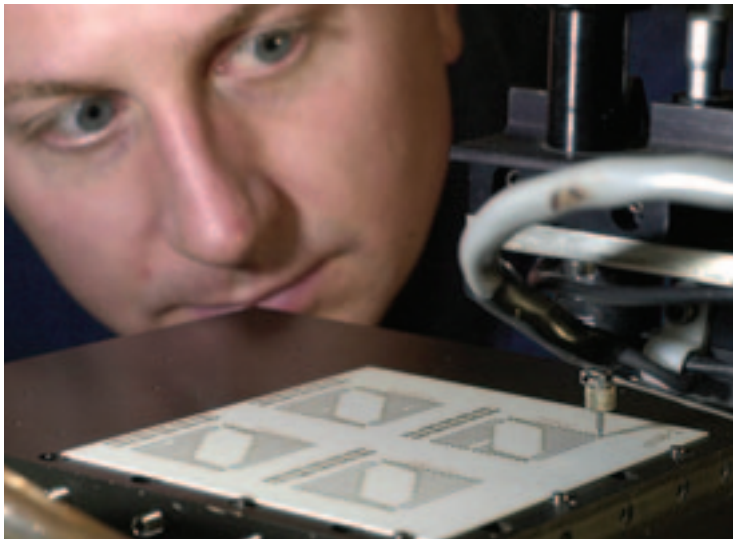
those in use today inscribes features that could be as small as 20–25 nanometers. (A nanometer is one-billionth of a meter.) This process required the development of the capacity to use light, invisible to the eye, to create smaller and faster circuits for memory chips, microprocessors, and application-specific integrated circuits.

The gleaming EUVL tool was assembled at Sandia California in a historic partnership with semiconductor manufacturers. It was unveiled in April 2001 at a landmark celebration. The five-year research program had been launched four years before by a consortium that now includes Intel Corp., Advanced Micro Devices, Micron Technology, Motorola Corp., Infineon Technologies, and IBM Corp. Industry is spending $315 million to advance research in this process, and three national laboratories—Sandia, Lawrence Livermore, and Lawrence Berkeley—serve as a virtual national laboratory.

Sandians and researchers at Brown University, combining unique chemistries and semiconductor techniques, demonstrated a tiny laser that produced, for the first time, ultraviolet light that can be converted to white light. These lasers, built like semiconductors, will be part of a revolution where current lighting will be replaced with solid-state lighting. The improved efficiency will result in a huge energy savings and less pollution.

In another development, Sandia researchers have created an innovative way to build multilayer electronic components that are smaller, more flexible, and more complex than those produced by standard lithography. The process uses direct-write, a computer-automated device that precisely prints ceramic and metallic slurries on a substrate. This allows components to be built using a variety of materials and complicated shapes. Because it eliminates tooling such as screens and masks, this new system is extremely valuable for rapid prototyping of electronics and is ideally suited for fabricating highly customized circuits, which are especially appropriate for Sandia technologies.

We also fabricated micron-scale tools using a focused ion beam. Previously, miniature-machining techniques were limited to the 50–100 microns scale. It is now possible to directly fabricate components as small as 1 micron out of traditional design materials such as stainless steel, alloys, and ceramics. We expect this technology will have application in microactuation, microanalysis, medicine, and component fabrication.



Direct-write—Paul Clem watches a micropen deposit ink to write a complex electronic circuit pattern.

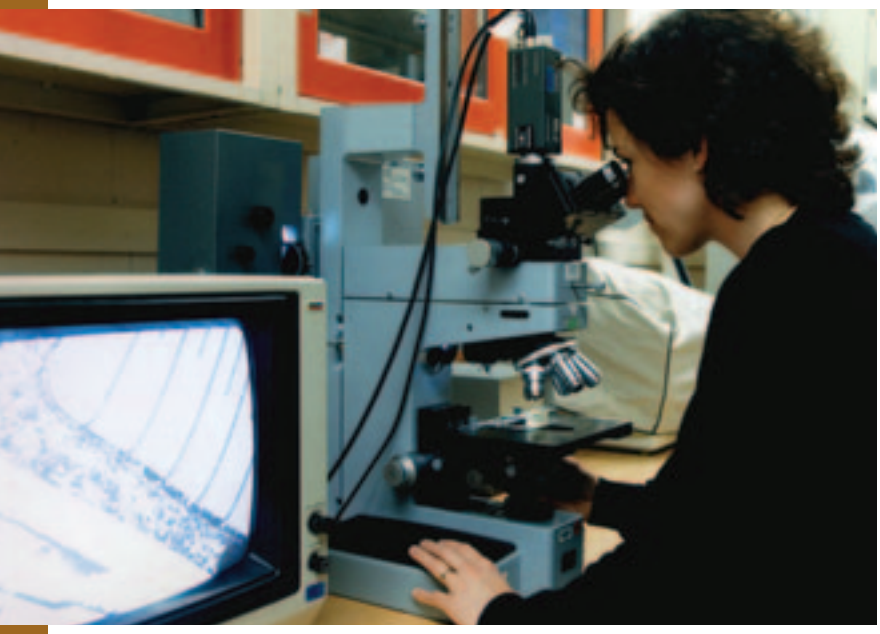
Sandia researchers, working with an international team of scientists, developed a photochemical technique for producing unique nanostructures. Regions of silica gels containing photo-activated acids are exposed to ultraviolet light and become more dense to make a diffraction grating or other optical devices.

Sandia scientist Jung Han with the prototype ultraviolet solid-state microcavity laser. Vertical-cavity surface-emitting lasers (VCSEL) coated with phosphors have the capability to generate the white light most prized for indoor lighting and last up to 10 times longer than fluorescent tubes.

Building Molecules One Atom at a Time

Miniaturizing the industrial revolution by at least a million times is just the beginning of our intelligent microsystems program. Manufacturing has gone about as far as it can go with microdevice engineering. Further progress will require an increased understanding of the science of materials behavior at the nanoscale level—the point at which atoms and molecules interact.

Sandia's computational modeling of biological and chemical materials allows researchers to manipulate molecules one atom at a time, or to quickly sift through thousands of compounds for one with specific properties. Combined with our strengths in materials sciences, these new materials now function as supersensitive coatings and molecular bundles with a vast potential for environmental cleanup, virus detection, and cancer treatments, among others.



Jill Glass studies the microstructure of ceramic materials. Research such as this leads to strategies for improving materials.

This year, Sandia scientists used lab supercomputers to custom-design chemicals with flypaper-like arsenic-trapping properties. These materials, specific anion nanoengineered sorbents (SANS), are described in detail in the Energy and Critical Infrastructures section of this publication, as are new microporous materials called Sandia octahedral molecular sieves (SOMS), which could help purify industrial processes and waste streams, or filter out valuable chemicals for reuse.

Nano-Microscope Reveals Self-Assembly Processes

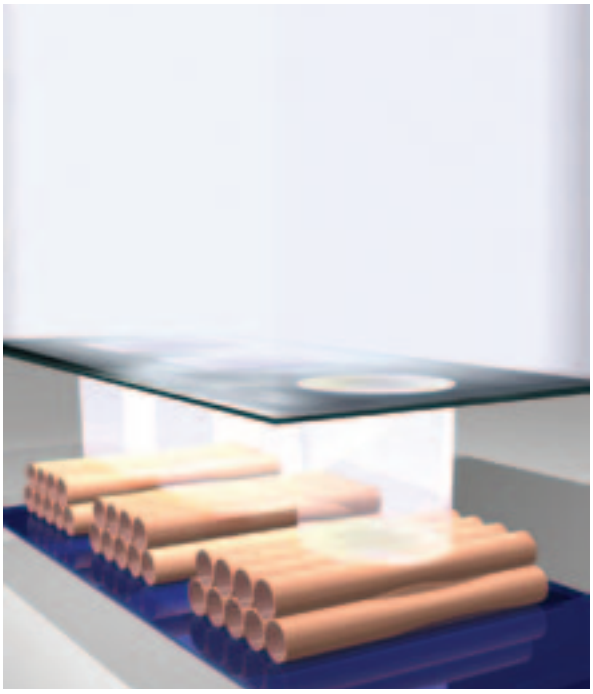
The low-energy electron microscope is one of Sandia's specialized tools for learning how certain combinations of atoms spontaneously self-order into stunning structures consisting of nanometer-sized dots, stripes, or polygons. Such nanostructured materials frequently exhibit unique mechanical, optical, or electronic properties. Recent experiments provided the elusive proof of a simple theory that explains how interatomic forces compete to produce these structures. Once understood, scientists can exploit self-assembly to synthesize new classes of materials with tailored properties for multifunctional, miniaturized actuating or sensing systems.

Using this unique microscope, Sandians discovered the surprising way that bronze alloy forms when tin is evaporated onto copper. Microscopic tin crystals slowly shrink while "grazing" the copper surface in an entertaining, almost lifelike dance. It appears that repulsion between tin atoms within the crystals and tin atoms left in their wake push the crystals forward, away from the bronze in their tracks. Surface forces drive the process, which might enable small, new devices.

BIOTECHNOLOGY—SCIENCE FOR THE 21ST CENTURY

The challenges of physics in the 20th century are being supplanted in the 21st century by the challenges of biology. Protein engineering—designing sequences of proteins to accomplish goals from curing diseases to rendering toxins harmless—is the next great scientific challenge. Few, if any, substances in nature are more specific and sensitive than proteins. Harnessing their power will provide unprecedented opportunities for Sandia and the nation to achieve our science and technology goals.

Sandia's biotechnology program has bolstered our work in many different areas. (These advances are described in other sections of this publication.) Biotechnology allows us to understand, for example, the specific actions of biological and chemical threats, and to design highly effective detectors and countermeasures.



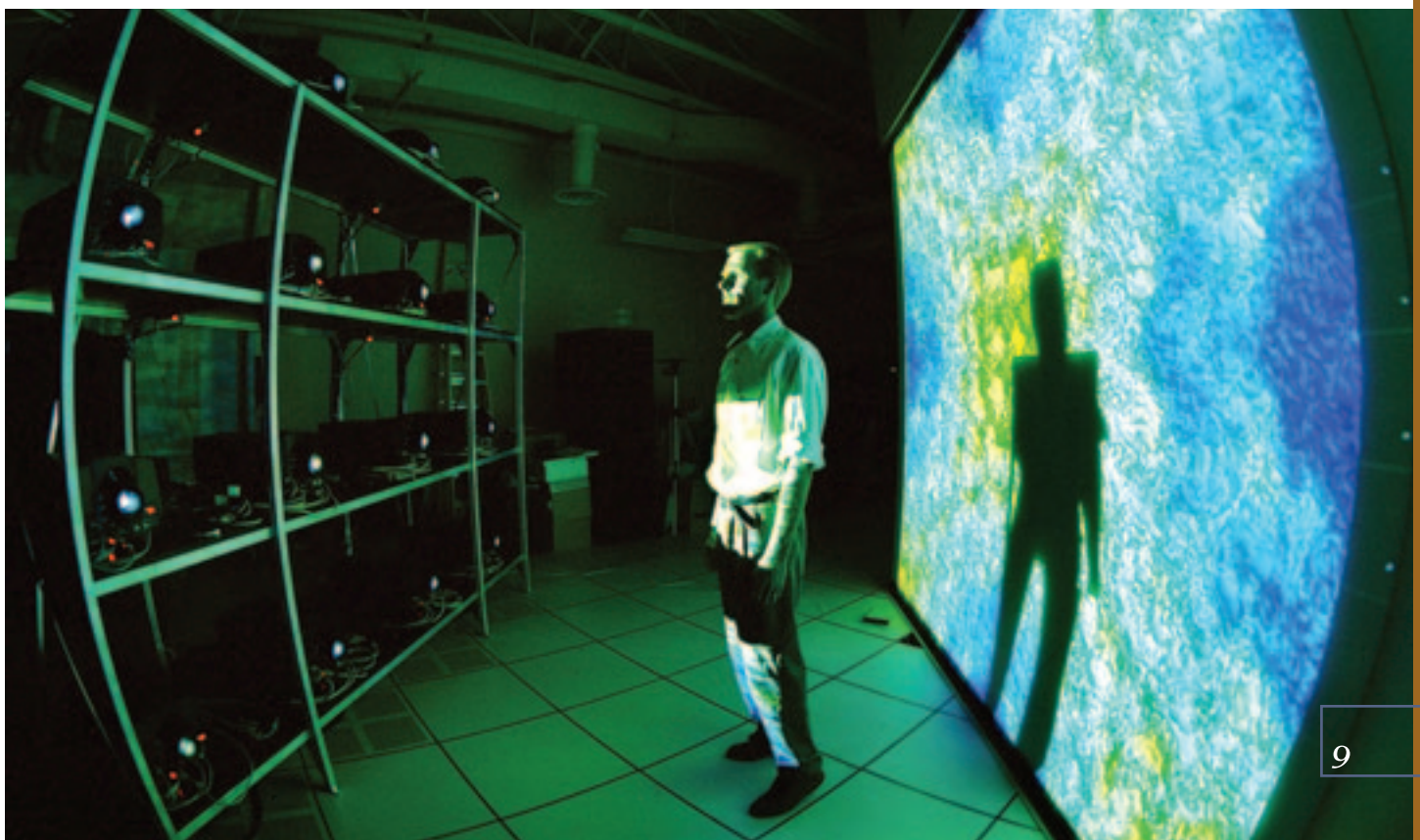
A graphic representation of a beam of ultraviolet light influencing the pore size of a self-assembled nanostructure. The area in light is being shrunk.

Sandia is applying its strength in computational modeling and simulation capabilities to the subtle but ultimately precise interactions of biological substances. That work has yielded advances just as it has in chemistry and physics. Sensors based on the reactions of lipids or fatty acids, or the vibrational response of other biological substances, are improving our abilities to detect and destroy potentially harmful substances.

Equally important are our theoretical advances—our ability to reduce seemingly intractable problems to a manageable size and to prove that the reduction is valid. In structural biology, the ability to reduce problems and visualize results is a critical national capability, especially in the area of protein folding, where sequences of amino acids, the building blocks of proteins, change from long strands to functional machines by folding at certain junctions at precise angles. Even a relatively short sequence of 100 amino acids presents more possibilities for folding than there are atoms in the universe. Advanced algorithms, and the computing and visualization powers to back them up, are providing insights into a process that may only be solved by theoretical means.

INFORMATION TECHNOLOGY AND A NEW INITIATIVE

Computational and materials sciences conducted at the micro- and nanoscale are blurring the boundaries between physics, chemistry, biology, and computers, as well as



David Logsted checks the alignment of Sandia's 16 digitized projectors that create an image on a 20-million-pixel screen that makes high-definition television look grainy by comparison.

Sarah Allendorf

Steeling Time in the Chemistry Lab

The vistas of open hillsides from the office where physical chemist Sarah Allendorf coordinates combustion research stand in stark contrast to the gritty settings where she puts scientific concepts into practice.

"When I first came to work at Sandia in 1993," she recounts, "my group was five months into a major proposal with the American Iron and Steel Institute. I already knew I wanted to do laser chemistry—I loved the connection with physics—but I also knew I would prefer working on real-world applications such as this."

The ongoing project brings laboratory research lasers into the harsh environment of a steel mill. By illuminating chemicals in the vapor above the melt, the lasers help track the process—like a chef sniffing the aroma of a pot of soup—indicating in real time when the molten iron has finished converting to steel. If the melt is halted too soon or proceeds too long, it takes extra time and energy to repeat the process. Monitoring in real time not only indicates when the steel is finished, it also saves time normally taken to stop and sample the molten metal. Adjustments can be made along the way as the monitor tracks the progress.

Lately, Sarah combines research challenges and family time by working just four days a week. Still, she beams about her long days in the field, helping to install monitoring devices at a steel mill in Canton, Ohio.

"It was really quite wild," she says. "The science is very straightforward in what we're trying to do, but the engineering to make it work is very challenging."

Sarah received her doctoral training in the Stanford University lab of Richard Zare, a pioneer in laser research. Now she pulls together teams for wide-ranging monitoring applications: at an incinerator in North Carolina; at steel mills in Maryland, Pennsylvania, Ohio, and West Virginia; and among contained explosives-destruction tests in Nevada and California.

the cognitive sciences, creating ever-larger amounts of data. Pertinent data may be recorded at any scale from a single, barely detectable femtosecond subatomic event to terabytes-per-second streams of multichannel satellite spectral data.

Insight to map protein interactions. For our nuclear weapons mission, we developed inexpensive visualization hardware 100 times more capable than commercial hardware.

These achievements—advancing our ability to assemble and manage our knowledge—are still essentially just tools.

Sandia's visualization design centers, equipped with advanced computers and display systems, allow scientists and engineers to collaborate remotely.

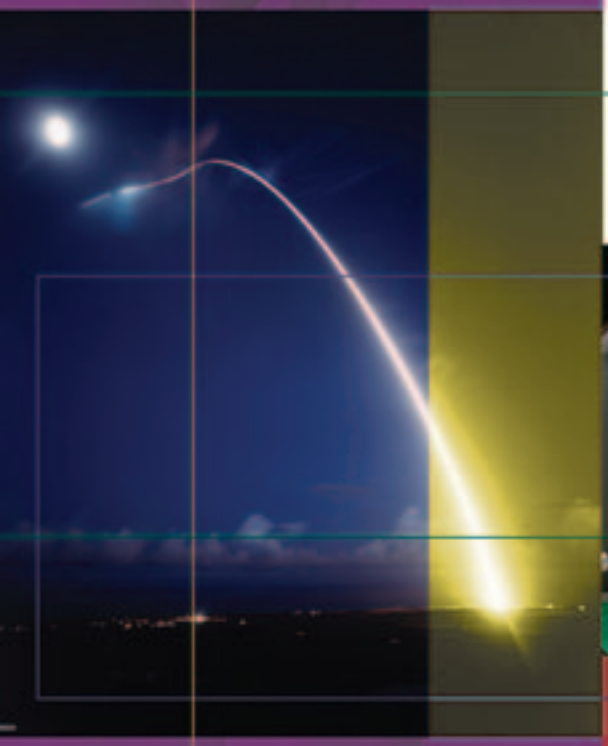
Getting a handle on what we sense and think was a problem when the Greek philosophers wrote about epistemology—the study of knowledge and how we acquire and use it. Scientific advances, compounded by engineering advances, and compounded again exponentially by data-acquisition and processing advances, have led to great progress. And yet there exists the strong possibility of even greater missed progress because we simply cannot comprehend all that is happening.

Do we truly have a handle on the progress of science and technology in the modern world? In previous years, we have developed information-technology tools such as science maps that show science research as a physical terrain, and visualization tools such as Vx Insight, which reduce terascale data sets to understandable dimensions that include sound and touch as vital and often overwhelming enhancements to understanding. Today, Sandians use Vx

With the aid of Sandia's computer science and even broader information-management expertise, we are now striving to formalize a methodology for converting exponentially increasing streams of data into knowledge that can be used by decision makers. This new initiative, which we call cognotechnology, focuses on the human-machine interface, recognizing that machines are increasingly intelligent and capable of supplying overwhelming amounts of raw data. With Sandia's proven abilities to reduce theoretical and practical problems to a size within reach of human comprehension, a new era of human-machine interactions will emerge.

Using machines as an extension of human thought is a science and technology "grand challenge" beyond even that of nano- and biotechnology. We at Sandia are preparing to meet that challenge.

Guardians of the Nuclear Arsenal



From top: missile launch; Ken Chavez with wind-tunnel model of B61-11 weapon; concrete model of a nuclear power plant containment vessel; computer modeling of molecules in zeolite.

Sandia's nuclear weapons mission helps preserve our national security and technological superiority. Only the most advanced and failsafe technologies and processes fulfill our responsibilities to the nation to ensure the safety, security, and reliability of our nuclear arsenal.

The nation's sustained support of Sandia has resulted in an unparalleled institution that conducts world-class science and engineering for the most critical national security missions. Our research laboratories and facilities for large-scale testing and computational simulation are national treasures that are helping America achieve a more secure future.

Ultimately, our nuclear deterrent lies in the scientific and technological capabilities of Sandia's people and their ability to develop science and engineering solutions to national security problems with the highest degree of confidence. The nuclear weapons program at Sandia provides the foundation for workforce stability and technological revitalization. Scientists and engineers are drawn to Sandia by the grand challenges of our work, by unmatched facilities in which to conduct breakthrough research, and most of all, by the desire to render, as their honored predecessors have, "exceptional service in the national interest." That is the heritage and continuing contribution of Sandia's nuclear weapons mission.

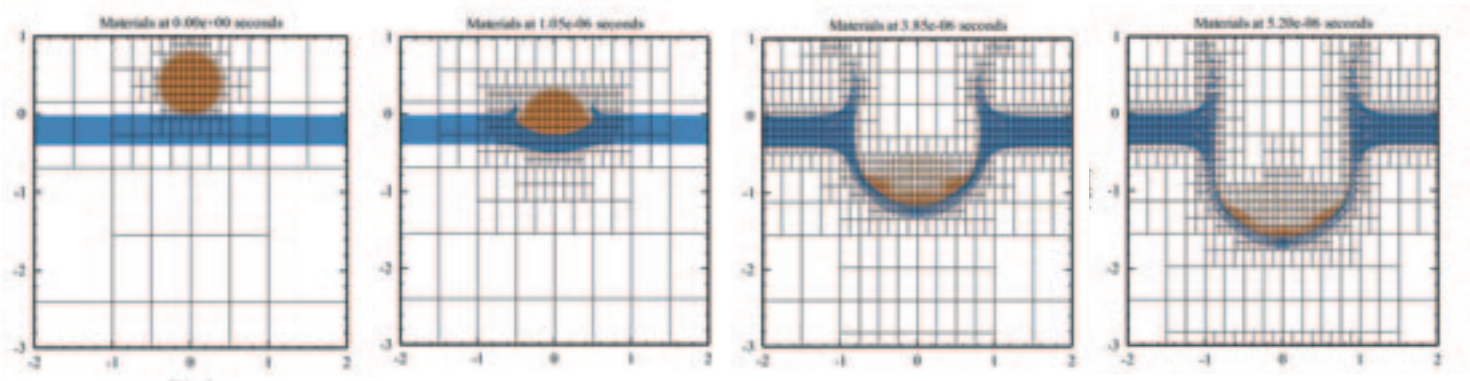
Tom Hunter,
Senior Vice President
Defense Programs

A NUCLEAR WEAPONS ENGINEERING LAB

Sandia is first and foremost a steward of our nation's nuclear stockpile. A failsafe nuclear deterrent is vital to minimizing our nation's vulnerability to attack. Certifying and preserving that deterrent remains our primary mission. Sandia's responsibilities in this arena are broad. Working with the strategic leadership of the National Nuclear Security Administration (NNSA), we advise the U.S. Strategic Command; we have supported the Panel to Assess the Reliability, Safety, and Security of the U.S. Nuclear Stockpile; and we have assisted the Hamre Commission to study science and security functions of the NNSA and Department of Energy (DOE).

With the retirement of some production agencies within the nuclear weapons complex, Sandia must bolster its production capabilities.

In 1992, we accepted responsibility for producing electronic and limited life-cycle components such as gas generators. Sandia's advanced manufacturing capabilities are models for manufacturing low-volume, high-reliability parts for the nuclear weapons complex. Since 1992, we have delivered more than 40,000 components. Almost 20 private sector companies that partner with Sandia manufactured more than 6,400 parts over the past year. Products include actuators, thermal batteries, igniters, gas generators, capacitors, magnetics, frequency devices, and electronic components.



The latest version of CTH, Sandia's widely used shock wave physics computer code, is being made available to customers nationwide. The code simulates high-speed impact and penetration phenomena involving a variety of materials.

The U.S. nuclear weapons stockpile requires exact engineering and the integration of nuclear weapons with their delivery systems. Sandia researches, designs, and develops 97 percent of the approximately 6,500 components of a modern nuclear weapon. And we preserve the nation's capability to develop—should the need arise—new options for national defense.

Each year Sandia independently determines whether the weapons of our nuclear arsenal are safe, secure, and will function as designed. We develop new technologies for weapons and enhanced surveillance programs, and produce alterations and modifications of weapons systems to maintain their capabilities. This systematic and objective scrutiny of all aspects of our nuclear arsenal maintains and sharpens our system analysis and scientific capabilities. In addition, we develop technologies to safeguard the production complex.

Sandia achieved a significant milestone by realizing 100 percent first-time acceptance by the NNSA's Albuquerque office.

In 1994, we accepted responsibility for producing neutron generators, the warhead component that serves as the spark plug for nuclear weapons. The success of the W76 neutron generator project shows that we can design, qualify, and deliver on schedule this and other limited life-cycle components without underground testing.

Sandian Pauline Ho watches as plasma created by an electric field passes through nitrogen-oxygen gas.

Maintaining our Nation's Nuclear Weapons—Stockpile Life Extension Programs

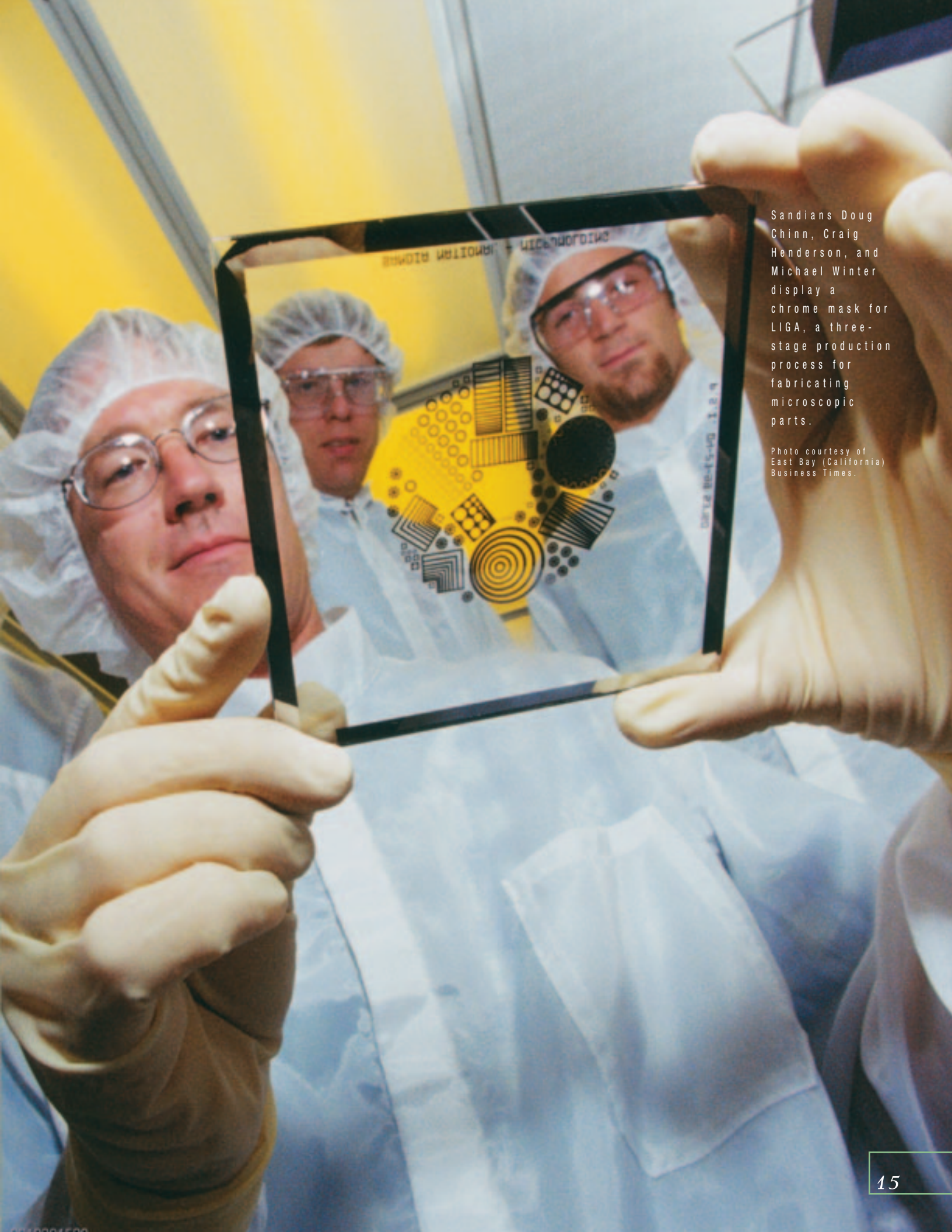
The Nuclear Weapons Council authorized the W76 Trident and W80 cruise missile Stockpile Life Extension Programs (SLEP) after a multiyear effort to assess the warheads' state of health, develop refurbishment options, and plan development and manufacturing schedules.

The conceptual designs challenge Sandia to achieve technical innovations and employ new modeling and simulation tools. Sandia is required to develop new designs for the electrical systems, neutron generators, gas-transfer systems, and several new structural components. It also must achieve significant improvements in surety. These programs will introduce a new generation of scientists and engineers to the daunting challenges of maintaining our national security in the face of evolving threats, without actual nuclear testing.

With each new generation of scientists and engineers entering Sandia, we are determined to build on our advances in innovative ways. We preserve, as best we can, the wisdom, art, and science of our pioneers through the Knowledge Preservation Project, the Weapons Intern Program, and the willingness of older Sandians to serve as mentors.

As the stockpile ages and weapons components show signs of degradation, Sandia designs and validates new War Reserve quality components that employ technologies often many generations ahead of the previous ones. These new technologies are far more reliable and many times lighter and smaller. When a commercial vendor no longer supplies components to War Reserve quality, or there is a ban on materials used in an earlier production process, Sandia steps in to fill the void.

Technologist Benjamin Thurston examines the debris shield that protects the focusing lens of Z-Beamlet, the third largest laser in the world. Z-Beamlet is a diagnostic tool that is used to measure whether Sandia's Z accelerator—the most powerful laboratory producer of X-rays in the world—spherically compressed a simulated fusion pellet during firing.



Sandians Doug Chinn, Craig Henderson, and Michael Winter display a chrome mask for LIGA, a three-stage production process for fabricating microscopic parts.

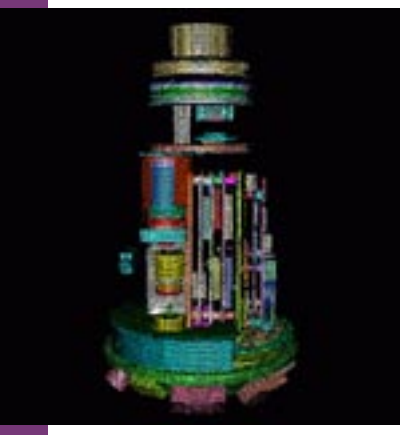
Photo courtesy of East Bay (California) Business Times.

Our successes this past year included the following:

- Sandia developed a number of application-specific integrated circuits (ASICs). These circuits, about the size of microchips, replace much larger printed-wiring boards (PWBs) that held individual electronic components. Modern ASICs are much better suited to withstand the hostile environment of weapons than older PWBs. The new, smaller units also provide more space for other in situ testing and diagnostic systems.

- We demonstrated prototypes, containing a wide range of new technologies, of future firing and fuzing systems. These technologies included the use of micromachine and LIGA stronglinks (LIGA is a German acronym for a three-stage production process for fabricating microscopic parts), optical firing sets, and optical charging and triggering of capacitors. Through the use of simulation and rapid-prototyping tools and techniques, we were able to go from paper designs to hardware in less than a year. In addition, these tools allowed us to evaluate and solve a variety of design and manufacturing issues before the prototypes were fabricated. A new energy-storage device uses technology that is half the size and 10 times less expensive to produce.

Sandia has been a world leader in developing sensors that can "see, hear, and feel" substances or events thousands of times more sensitively than humans can. We continue to work on miniaturized sensors that monitor the health of nuclear weapons. This work has far-ranging applications in other missions, as described elsewhere in this publication.



Sandia's CUBIT advanced meshing computer software is used to model the W76 weapon.

The nuclear weapons program completed final design of the $400 million Microsystems and Engineering Sciences Applications (MESA) complex and chose an architectural and engineering firm for construction. MESA will consist of the facilities and equipment required to design, integrate, and fabricate prototypes, and qualify integrated microsystems for weapon components, subsystems, and systems for the U.S. nuclear weapons stockpile. It will incorporate the work of other DOE initiatives, such as:

- the computations and simulations of the Joint Computational Engineering Laboratory (JCEL)

- the computing power and codes of the Accelerated Strategic Computing Initiative (ASCI)

- the communications infrastructure under development at the Distributed Information Systems Laboratory (DISL) at our California site. Funded by ASCI, DISL will house computer scientists, analysts, and weapon design engineers to research and deploy the advanced computing and networking technologies needed to support the nuclear weapons stockpile stewardship program.

MEETING THE GRAND CHALLENGES OF COMPUTATIONAL SCIENCES

Sandia's computer expertise is world renowned. We are the only institution to win two Gordon Bell awards, presented for surmounting "grand challenges" in computer sciences. Sandia developed the science and methods for making thousands of processors work together efficiently, when most people believed only 10 processors were the practical limit. We also discovered a way to computationally solve very large problems in relatively few steps, when most people believed they would take millions of steps.

Our breakthrough modeling and simulation capabilities are used to scientifically model the entire life cycle of nuclear weapons. This year we continued our progress on many fronts:

- ASCI is on path to achieve a breathtaking advance in computing power—100 trillion calculations per second (100 teraOPS) by 2006, or about 333 times faster than the approximately 300 billion calculations per second achieved in 1996. This year we began design of a new 20 teraOPS system, about 10 times more powerful than our current supercomputer.

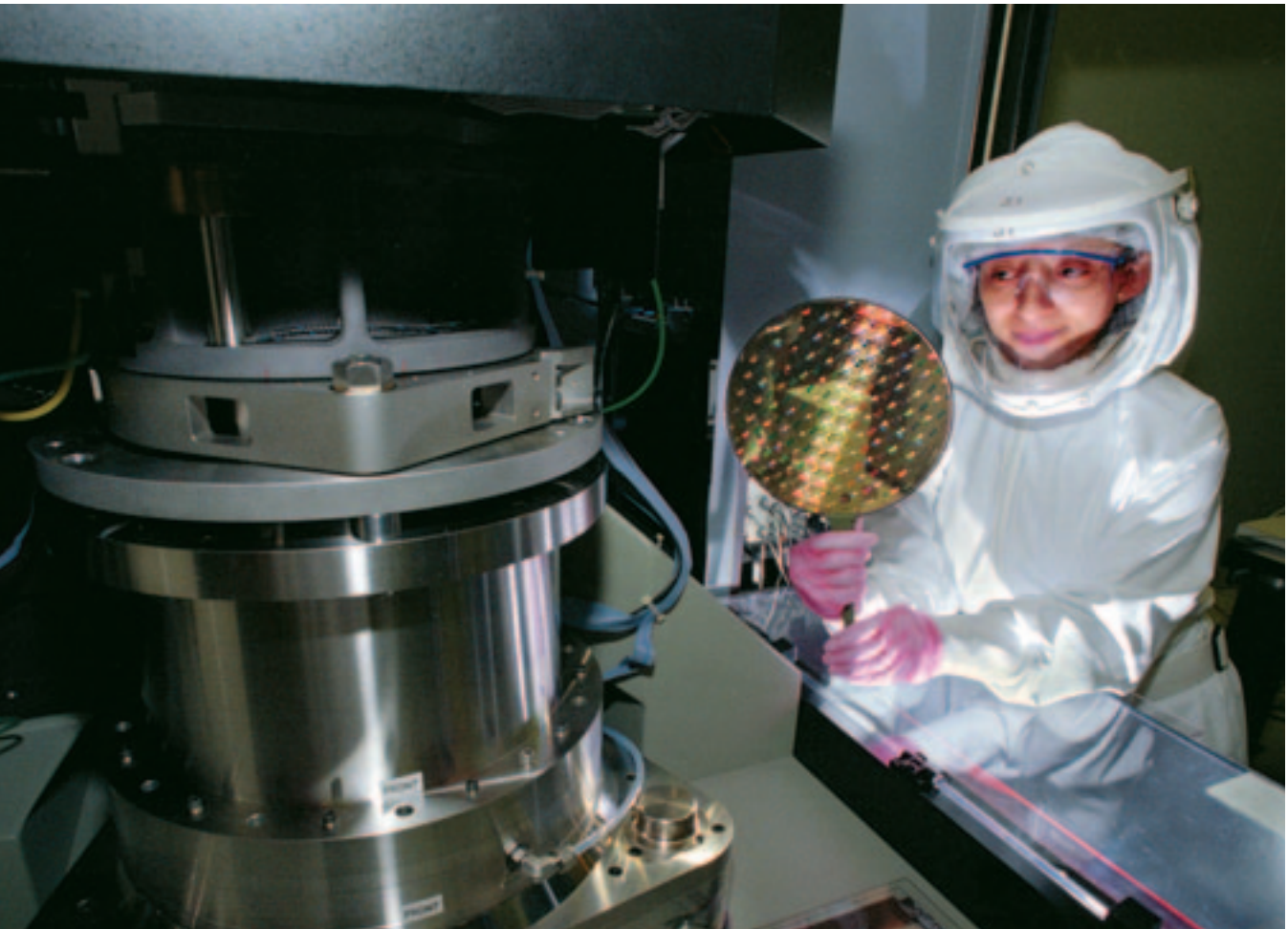
- Sandia signed a breakthrough cooperative research and development agreement (CRADA) with Celera, a Maryland company, which provided the first rough draft of the entire human genome. The third partner in this CRADA is Compaq Computer Corp. The next steps in mapping the human genome—refining the rough draft and then defining the function of genes—require computer power and expertise of the same scale as modeling nuclear weapons.

The Galileo spacecraft—equipped with microchips that were radiation-hardened by Sandia—was launched in 1989 and began orbiting Jupiter in December 1995. It was expected to last two years in that harsh environment. By December 2000, the spacecraft had received three times the cumulative radiation exposure it was expected to withstand and was continuing to make valuable scientific observations.

- We developed a high-performance computer graphics rendering system to handle the large data sets generated by the ASCI supercomputers, which exceeded the capability of previous computer graphics systems. Sandia used $350 PC graphics cards to build a scalable rendering system that performs 100 times faster than the largest commercial system. This technology is key to ASCI's success.

- Sandia continues to render the Intel Pentium® microprocessor capable of surviving the radiation of weapons and deep-space environments. Intel granted Sandia a fee-free license, saving taxpayers millions of dollars. The "hardening" of ever-smaller and more sensitive chips is one of Sandia's longstanding contributions to national defense and aerospace industries.

- We successfully simulated a section of the microprocessor using the Sandia-developed ChileSPICE™ circuit simulator, which carried out simulations three to 10 times faster than commercial simulators. The improved performance will lead to better circuit designs. Initial performance evaluations of Xyce™, the next-generation massively parallel circuit code, show a further dramatic improvement. ChileSPICE and Xyce are just two examples of how Sandia develops new software applications, or enhances existing software technology, to meet critical nuclear weapons needs.



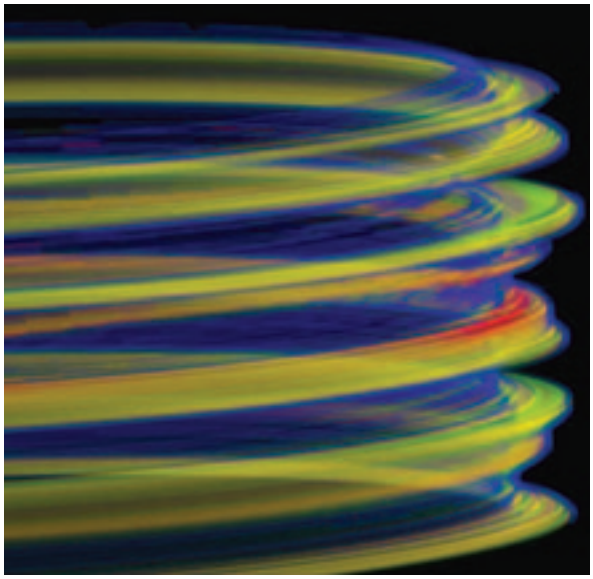
Technician Denise Carrillo inspects a newly metallized wafer in Sandia's Microelectronics Development Laboratory.

Carl Leishman examines one of many racks of computers that collectively form the basis of Sandia's Cplant system, the largest Linux cluster in the world.

- We used the SALINAS massively parallel 3-D structural dynamics code and completed critical simulations of the W76 system's response to hostile radiation environments. Sensitivity and optimization analyses were performed on the firing and fuzing model using Sandia's DAKOTA software package. The CUBIT advanced meshing software generated a high-fidelity model for timing and scaling studies. This comprehensive system response simulation was an important milestone in the ASCI program.

- We made significant advances in the parallel performance and physical fidelity of our suite of electromagnetics and plasma physics computational tools, named EMPHASIS. We used EMPHASIS to qualify systems in intense electromagnetic and X-ray environments, to design high-frequency electronics, and to model pulsed-power components.

This three-dimensional ALEGRA simulation is used to study the complexity associated with Z-pinch experiments.



- We used a microstructure model that can predict the accurate stress and failure response for component designs and manufacturing processes to optimize die design in a weapons component forging process. The model will lower the size and weight of automotive components, thus saving fuel and reducing emissions. Sandia was given an R&D 100 Award for the model.

- We adapted the Lightscape™ architectural lighting simulation to accurately model radiation transport in Sandia's Z accelerator, the world's most powerful electrical device and radiation source. Complementary research uses Sandia-developed software to find the optimal geometry for inertial confinement fusion components.

- Sandia's Cplant team developed a flexible architecture for continued computing expansion and a testing strategy to ensure a quality environment for the users. Cplant is now a tri-lab computing resource, extending its access to sister labs and to the open community. Cplant, short for Computational plant, is now the largest Linux cluster in the world with nearly 2,000 Compaq Alpha nodes.

FACILITIES TO ADVANCE OUR MISSIONS

This year we dedicated the Processing and Environmental Technology Laboratory (PETL), a $46 million facility that brings together our materials science work. Materials science—the study of materials and the creation of new materials—is a longstanding Sandia strength. This state-of-the-art facility will advance our research and attract new scientists and new programs. Exciting new research and development of ceramics, composites, superconductors, and new supermaterials will occur here.

This year we also completed the Gamma Irradiation Facility. Subjecting components and other electronic systems—such as those in an armored tank or airplane—to different types of radiation is an essential element of our experimental capabilities. When a nuclear weapon sits in the stockpile, it gives off low-level radiation. Over time, this exposure can damage components, eroding their reliability. The hostile radiation environment that a weapon or satellite encounters can damage electronics. Sandia has an array of experimental radiation facilities that can test everything from single components to large aircraft for their resistance to radiation.

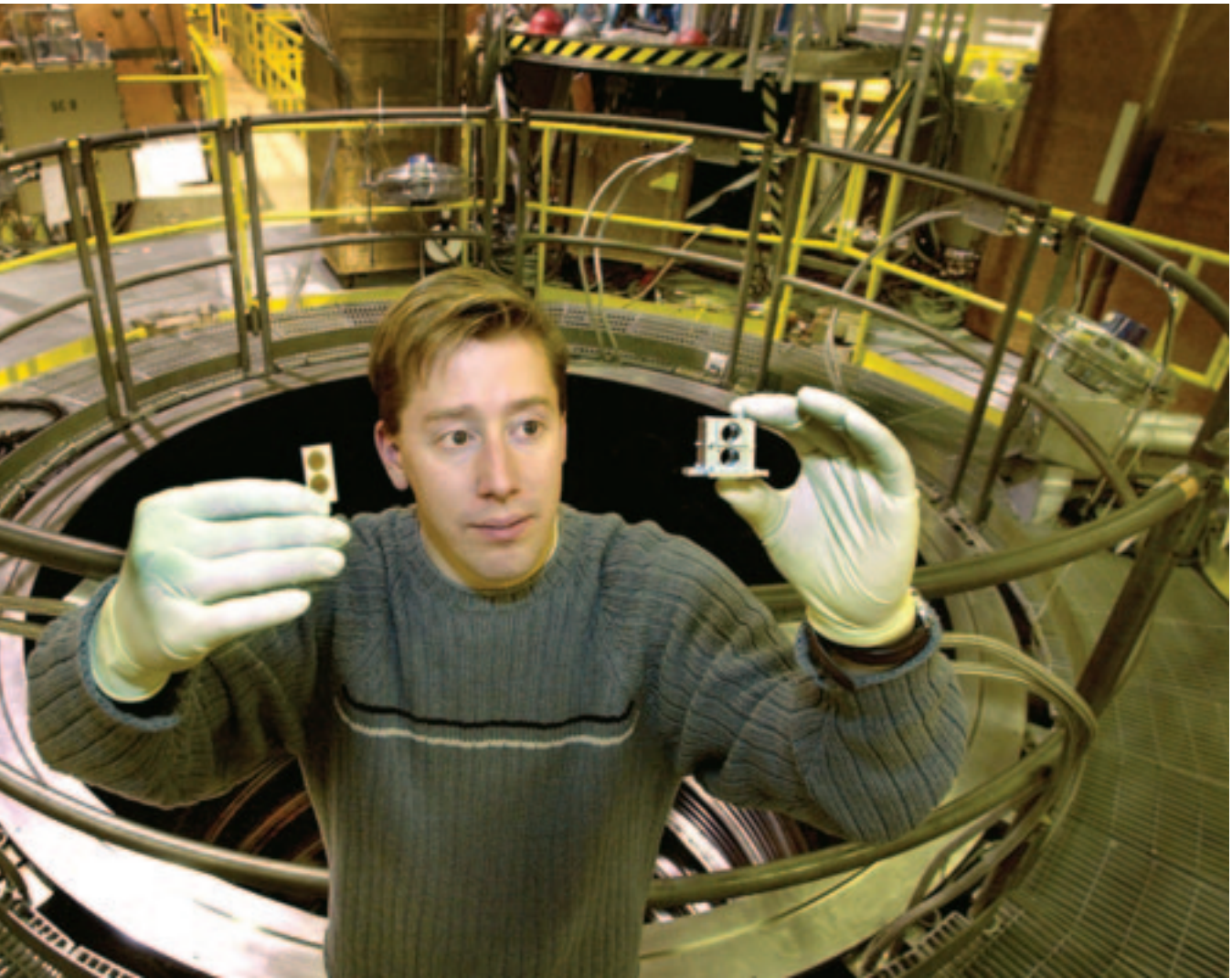
The In-Ground Storage Vault was designed and constructed to provide high-security, temporary storage for Sandia's pulsed reactor fuel materials. This state-of-the-art facility yields annual security cost savings of about $6 million and is the first step in a comprehensive plan to ensure that the pulsed reactor is available to meet essential nuclear weapons testing requirements. That plan will culminate in construction of a new high-security Sandia Underground Reactor Facility to house future operations.

A new Weapon Evaluation Test Laboratory will blend the best of the core surveillance and enhanced surveillance programs, and will begin to move the DOE toward a predictive capability.

These enhancements were just the beginning of a proposed $90 million revitalization program for our test facilities, which includes a refurbishment of the Z accelerator.

EXPERIMENTAL SCIENCE AND FLIGHT TESTS

Continuing our remarkable progress with the Z accelerator, we developed a revolutionary capability to magnetically launch dime-sized pellets to velocities exceeding 44,000 mph. This technique enables experiments that approach the velocities of nuclear explosions, a breakthrough that enables calculation of the properties of materials in nuclear environments. The technique can also be used to study the impact of space materials on orbiting satellites, and the impact of kinetic kill weapons on their targets.



Sandia researcher Mark Knudson holds two flyer plates in his right hand and chambers of his high-tech gun in his left, used with the Z accelerator to launch dime-sized pellets to velocities exceeding 44,000 mph.

Rolf Riesen

Growing the Computational Plant

When Rolf Riesen mentions Hawaii, Antarctica, Siberia, and Alaska in the same breath, his voice reveals a sense of pride, excitement, and awe. Anyone unaware of Sandia's Cplant—short for Computational plant—might assume he is referring to geographical locations. But as a wall poster shows with its composite photograph of rows of processors, each dubbed with an exotic place name, he's actually citing key elements of Cplant, a supercomputer assembled at Sandia from off-the-shelf computers. Rolf is Sandia's lead Cplant software developer.

Cplant has grown to include 1,600 Compac Alpha computers, making it among the fastest computers in the world. The composite computer will be used to provide processing power for nuclear weapon design, and eventually, to make sense of the torrent of data obtained from simulating nuclear weapon explosions. Cplant also is a prototype for future flexible high-performance computing systems that will be less expensive than today's supercomputers.

Rolf and his team are still working to resolve scalability issues that arise when large numbers of computer nodes (in this case, individual computer workstations) are networked. As technical team leader, Rolf oversees the orchestration of those nodes into a single system.

"My job gives me access to big toys," he says. A few strokes on his keyboard and the computer responds with the message that 575 computers are awaiting his command. Such a resource would daunt most people, but to a computer geek like Rolf it poses the ultimate delight.

"There are not many places in the world where I can play with a supercomputer system for a few days," says Rolf. "It's exciting to actually get to try out theories."

Cplant's size doubles every year. After 2004, when the platform is expected to be fully scaled up, innovations will make the system not larger but faster. And Rolf will become more like a gardener than a toolmaker as he maintains, prunes, and recycles components for 10,000 computer nodes.

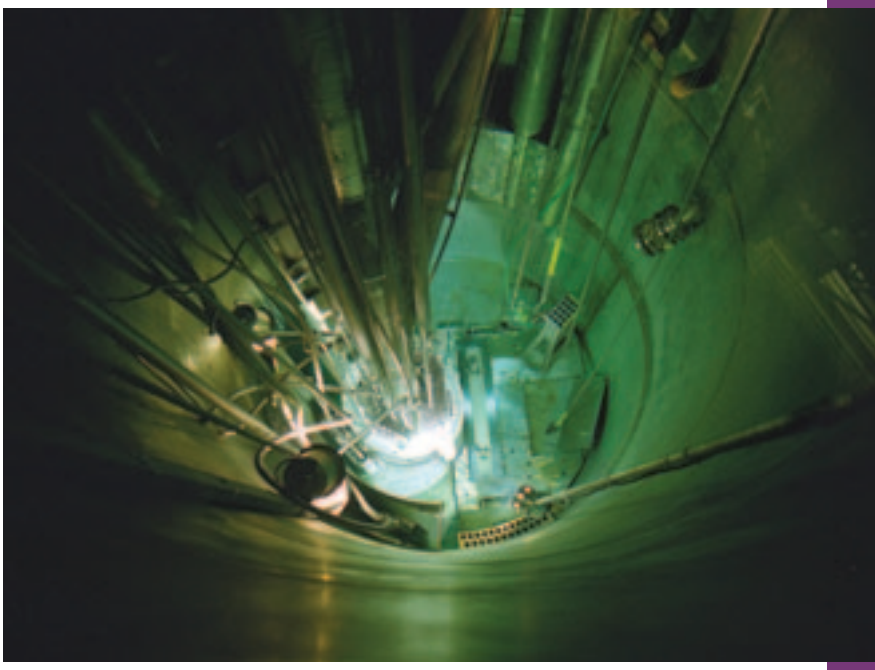
We are using a new ion beam analysis facility to measure—nondestructively and in depth—the constituents of neutron generator targets and sources. This facility, coupled with new plasma diagnostics and shock-physics capabilities, serves the neutron-generator program.

The Annular Core Research Reactor was modified to provide hostile environment testing for weapon components. The reactor was reconfigured for pulse operation with experiments located in the center of the reactor.

We completed the most detailed validation experiments ever performed on a nuclear weapon reentry body. These experiments successfully identified modes of vibration and discovered significant variability from unit to unit. The data will be critical to the validation of high-fidelity models for the nonlinear behavior of real weapon structures.

The W76 joint test assembly (JTA) telemetry system was employed in a reentry body, which was launched from a submarine, resulting in a successfully scored weapon-system test. The test validated advancements in radiation hardening, as well as the efficacy of Sandia's design methodology. An important first for this design was the digitization and transmission of neutron and firing-system waveforms. This system is significantly more complex, having 10 times the data rate of the original, yet the production costs are significantly less.

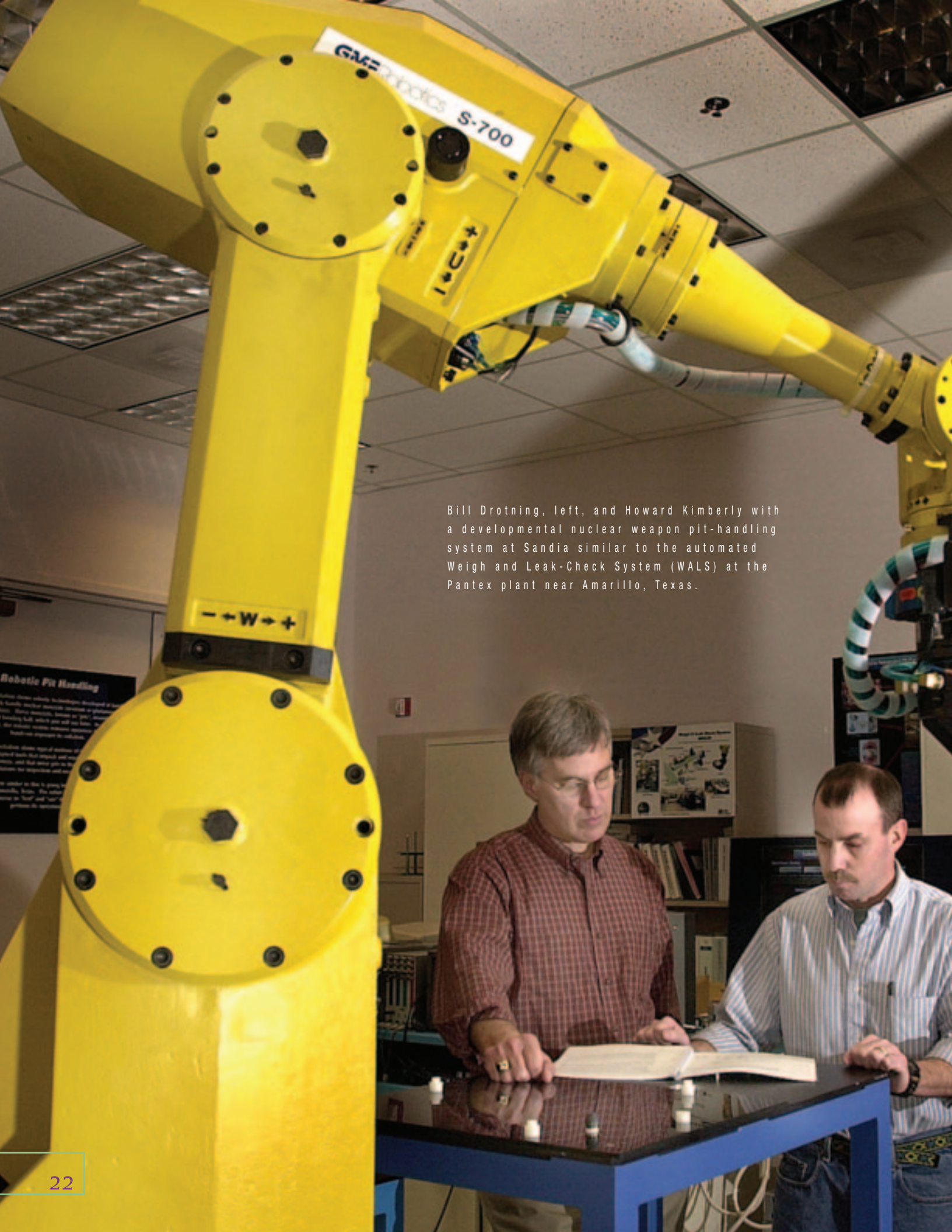
Submarine launch of the Tomahawk Cruise Missile.



Inside Sandia's Annular Core Research Reactor.

Engineers from Sandia and Lawrence Livermore national laboratories have begun a significant effort to develop a radically new W87 JTA telemetry system that will meet all of the needs of the Weapons Evaluation Groups, the Nuclear Design Lab, and the U.S. Air Force in a single instrumented reentry vehicle. The new system will acquire and transmit real-time test data from a test vehicle that will closely represent all aspects of a real nuclear weapon, including high-explosive initiation. This endeavor will enable the use of a single vehicle to meet the needs of multiple customers, thus achieving cost savings and more flexibility in the nuclear weapons flight test program.

A Sandia team in collaboration with Lawrence Livermore National Laboratory and Lockheed Martin Corporation designed and successfully flight-tested a warhead concept under the Submarine-launched Warhead Protection Program (SWPP). Warheads currently deployed by the U.S. Navy were designed and certified prior to cessation of underground nuclear testing and the closure of major NNSA weapon component facilities. The SWPP project investigated future options and exposed new staff to this important national security mission.



Bill Drotning, left, and Howard Kimberly with a developmental nuclear weapon pit-handling system at Sandia similar to the automated Weigh and Leak-Check System (WALS) at the Pantex plant near Amarillo, Texas.

ROBOTICS AT WORK

The noblest promise of robots has been to keep people out of harm's way—to perform tasks that are too dangerous, too difficult, or too monotonous for humans to do safely every time. Early this year at the Mason and Hanger Pantex plant near Amarillo, Texas, a Sandia-developed robotic system performed such a task—it grabbed and moved a W80 pit across a room, marking the first time a robot had ever lifted a nuclear weapons pit.

For national security, Sandia robotic systems autonomously watch for proliferation activities and guard nuclear facilities, surveil and remediate hazardous sites, and disassemble old munitions. For industry and medicine, Sandia has delivered flexible systems that are now at work performing everything from single, repetitive manufacturing tasks to enhancing a surgeon's precision and steadiness during delicate operations.

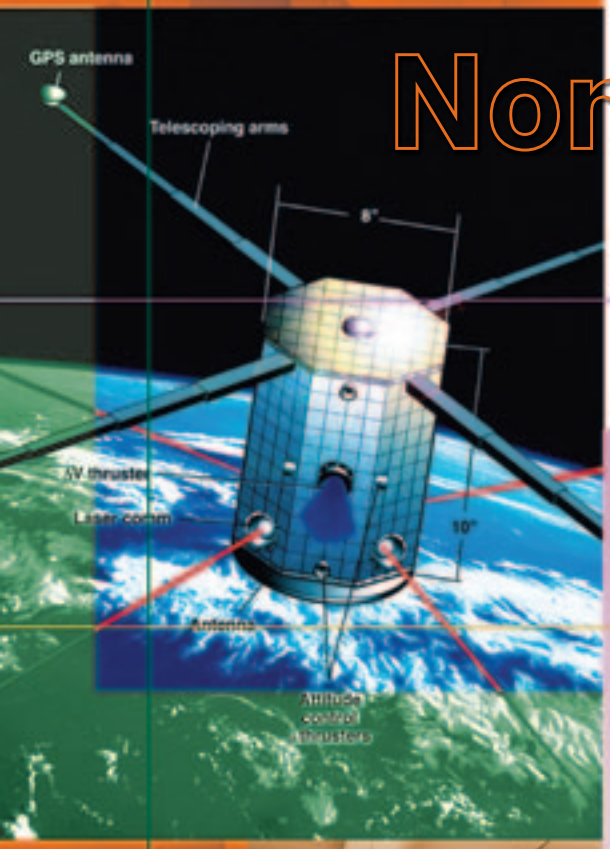
KEEPING OUR LAB SECURE

The National Nuclear Security Administration's Office of Transportation Safeguards (OTS) must meet the highest security standards to ensure the safe transport of materials throughout the nuclear weapons complex. Sandia helped meet four of six acceptable OTS security ratings from NNSA to allow the uninterrupted operation of the transportation fleet.

Sandia engineers prepare a commercial rad-waste transport container for a certification drop test required by the U.S. Nuclear Regulatory Commission.

Agile intrusion detection processes, new firewall management procedures, network scanning, switched high-speed networks, and the Sandia common operating environment have produced a robust cybersecurity architecture that has withstood the test of numerous audits and reviews. Viruses, Internet attacks, attempted intrusions, and unauthorized access are subject to rigorous scrutiny and are rapidly dealt with when detected. Online procedures, rapid response teams, and a sophisticated cyberarchitecture have created a state-of-the-art system designed to provide Sandia with an effective cybersecurity posture.

Nonproliferation and Materials Control for Global Security



Sandia's Nonproliferation and Materials Control Program develops solutions that reduce the vulnerability of the United States to threats of proliferation and use of weapons of mass destruction (WMD). These include nuclear, chemical, biological, and non-nuclear radiological weapons, as well as unconventional WMDs such as hijacked civilian airliners used to commit acts of war against our nation. Our solutions also address nuclear incidents and environmental damage.

As the attacks on the World Trade Center and Pentagon demonstrated, these solutions must be extraordinarily broad. Even though the United States and former Soviet Union (FSU) have agreed to shrink their arsenals, the threats posed by nuclear, chemical, and biological weapons remain. Transnational terrorism, regional instabilities, territorial ambitions, the spread of advanced military technologies, and the risk that WMDs could fall into hostile hands present a growing threat worldwide.

While our mission centers on WMDs and nuclear materials because of their high consequence, it also encompasses an increasing range of threats. Airliners used as WMDs crossed the threshold from acts of terrorism to acts of war. Many of our technologies for nonproliferation and materials control can be applied to these broader threats in a multilayered architecture that weighs threats and consequences.

Since the breakup of the FSU, hundreds of tons of weapons-grade nuclear material have been released from decreasing nuclear weapons stockpiles. The dramatically reduced security status applied to this material has resulted in an increased potential for nuclear terrorism and proliferation. The increased availability of nuclear materials, accompanied by a now-demonstrated willingness to use WMDs against the United States, makes unconventional nuclear and non-nuclear threats emergent and serious issues for our nation.

From top: Nanosatellite; mobile missile launcher; Cooperative Monitoring Center; remote monitoring technology.

Roger Hagengruber,
Senior Vice President
National Security & Arms Control

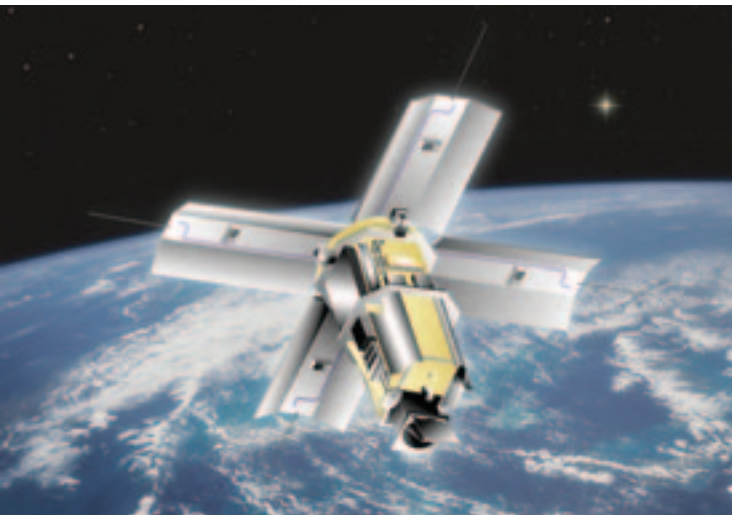
TECHNOLOGIES FOR NONPROLIFERATION

Political dissuasion, negotiation, and international agreements are the traditional first means of preventing the global spread of nuclear and other weapons of mass destruction (WMD). In a prolonged and sustained worldwide campaign to eradicate terrorism, other measures of war must be developed and deployed. Both diplomacy and war depend on the development of technologies and systems that can accurately detect, categorize, control, and assess proliferation dangers.

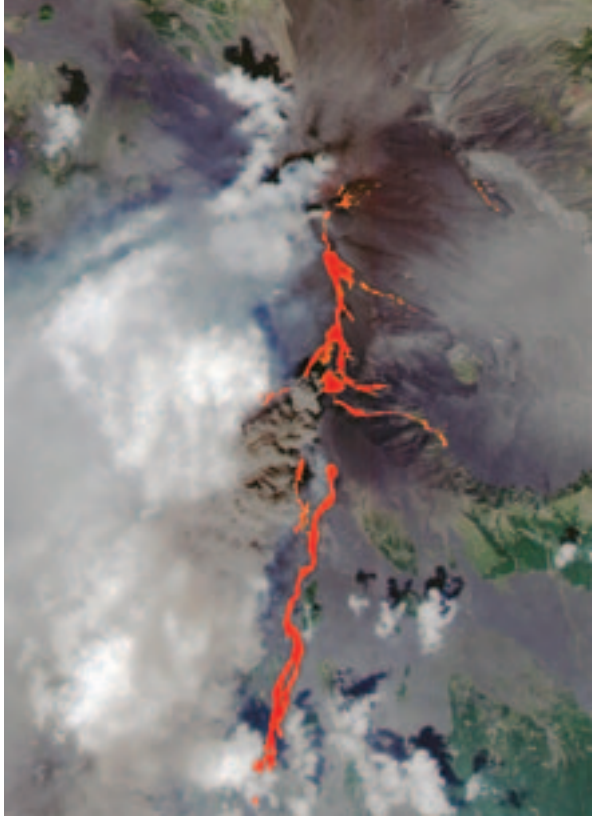
Sandia focuses on five areas for technology and system development:

- chemical/biological threats
- remote sensing and verification
- physical security and surety
- proliferation assessment
- material management and international security

Sandia's nonproliferation technologies range from microscopic sensors to large intelligence-gathering systems that monitor the globe. The technologies help to monitor compliance with international treaties. They also monitor indications of theft, diversion of nuclear materials, and of biological and chemical weapons programs.



The Multispectral Thermal Imager (MTI) satellite, designed and built at Sandia and now in Earth orbit, has a broad range of national defense and civilian applications ranging from treaty monitoring to mapping of chemical spills, waste heat pollution in lakes and rivers, vegetation health, and volcanic activity.



MTI satellite infrared image of Mount Etna, Sicily, showing hot lava in red.

Worldwide systems gather data from a vast array of sources and intelligently fuse these data streams into information that helps develop the knowledge needed for strategic decision making.

Beyond developing technology, Sandia supports the United States and international agencies by applying its nuclear and systems expertise in a wide variety of intelligence programs and vulnerability assessments. As the systems integrator for the nation's nuclear arsenal, we apply our accumulated knowledge to foreign technology assessments and to worldwide problems such as cybersecurity of critical information and global communication systems.

The New Threat: Advanced Chemical/Biological Attacks

Advanced technologies, especially when they include chemical or biological weapons, are threats of high consequence, capable of killing tens of thousands of people. In response, Sandia has been assessing the nature of the threats, and is developing both options and advanced systems and technologies to help thwart them.

The technology-development challenges include rapid detection and sensitive identification of chemical and biological agents, increased and more effective disease surveillance, and protection of critical facilities against chem/bio attacks.

Ronald Renzi, left, and Scott Ferko of Sandia's Advanced Microsystems Engineering Department in Livermore, Calif., inspect a prototype version of µChemLab/CB™, a portable system for detecting a broad range of chemical agents and biotoxins.

We have designed, fabricated, and demonstrated two prototype portable systems that can rapidly detect and analyze toxic agents. Extensive tests have demonstrated that our devices can identify specific agents with extremely high sensitivity in very short times. We have determined that these systems are not affected by the interference of common chemicals. For chemical agents, our system employs gas-phase analysis with a miniaturized chromatography column and a surface acoustic wave sensor, which together are smaller than a dime. For biotoxins, our system employs liquid phase analysis using Sandia-developed lab-on-a-chip technology. The µChemLab/CB™ (Chem/Bio) is further described in the Countering Threats section of this publication.

The PROTECT program is one of two domestic demonstration and application programs sponsored by the Department of Energy (DOE). Under this program, Sandia has developed tools and demonstrated technologies to protect U.S. facilities against chemical and biological attacks. As seen recently, facilities such as the World Trade Center are conspicuous and symbolic targets for terrorism. In particular, Sandia has developed software systems to evaluate dispersal of toxic agents in widely used public facilities such as subways and airports. We also have established a sensor test-bed in a major subway system where we have been evaluating the performance and reliability of both commercial and prototype toxic agents sensors in a real-world environment. We have used this information to help facilities owners and emergency response authorities develop more effective emergency response plans.

Sandia has developed software systems to evaluate the dispersal of toxic agents in widely used public facilities such as subways and airports.

Annette Sobel, M.D.

Helping People Through Technology

Four themes have guided the career of Brigadier General Annette Sobel: technology helping people, humanitarian assistance, global impact, and being at the forefront.

Annette established those principles following a tour in 1989 as a senior flight surgeon for an Army medevac unit in Panama. While flying missions, she saw people lose their lives because of shortfalls between technology and decision making. "Nothing makes as strong an impact as talking to victims' families," she says.

Determined to pioneer better ways to save lives through technology, Annette returned to school and earned a master's degree in human factors engineering. She then joined Sandia in 1992 and soon became one of three physicians on the technical staff.

Annette's determination has paid off. She led a team that was instrumental in developing a virtual-reality program to help train medical providers in the proper responses to chemical and biological terrorist attacks. More recently, her team has focused on countering bioterrorism by researching the brain's response to hazardous environments and by helping to develop a handheld brain injury detection device.

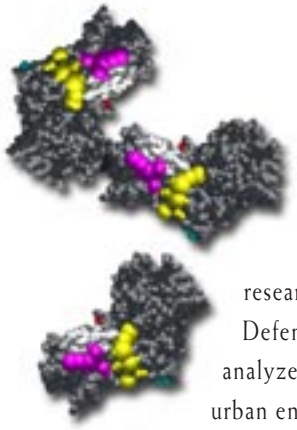
The National Science Foundation, which named Annette as a key contributor to the science of bioinformatics, singled out the work of her team for advancing the understanding of early environmental indicators of emerging infectious diseases and in developing computer agents to better predict the outbreak of infectious diseases.

She has worked to identify outbreak trends for dengue fever, an incurable viral infection that plagues urban populations in emerging nations. The fever can have a global impact when it causes political instability or forces the withdrawal of foreign investment into the afflicted country.

"I'm a generalist and a systems-engineering person, good at seeing the big picture and dissecting it into pieces that the technical staff can address," Annette says. "The hardest problems are what really interest me, especially if I can help someone."

We are
OUR PEOPLE

Sandia researchers have been applying computational biology capabilities to designing advanced ligands, small molecules that can selectively bind to toxins or pathogens to detect them or to inactivate them.



Combining systems assessment expertise with computational capabilities, Sandia researchers developed a Defense of Cities Study that analyzes potential attacks on urban environments and provides options for more effective civil defense.

The Rapid Syndrome Validation Project (RSVP) is a prototype system operating in New Mexico designed to provide improved disease surveillance. RSVP has already been effective as an early warning system to detect natural outbreaks of disease.

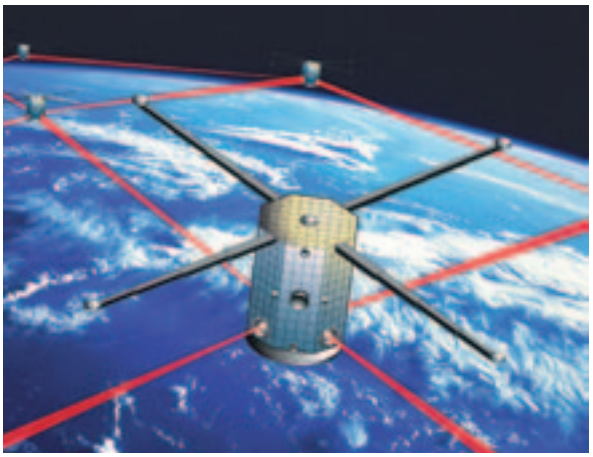
Using Sandia's advanced computational chemistry capabilities, researchers have been helping to design advanced ligands—small molecules that can selectively bind to toxins or pathogens to detect them or to inactivate them.

To more fully protect our nation against terrorist attacks, Sandia is researching applications such as unattended ground sensors, robotic platforms, and airborne and space-based platforms that will enable the rapid detection, identification, and mitigation of chem/bio agents. The remarkable accomplishments of Sandia's decontamination foam are described in the Countering Threats section of this publication.

Remote Sensing And Verification

While the entire nation cannot be protected against all threats, Sandia seeks to reduce its vulnerabilities by enabling a global virtual presence through the deployment of advanced sensing and imaging technologies.

The Mini Intrusion Detection System uses a passive infrared sensor that detects an intruder without his or her knowledge.



A cluster of nanosatellites communicates via laser intersatellite links.

Sandia researchers are advancing already established strengths in:

- signal collection, conversion, processing, and exploitation
- building and powering sensor platforms
- communications
- astrodynamics and attitude determination and control

Remote sensing information gathered from platforms that range from unattended ground sensors to unmanned aerial vehicles to new, smaller satellites, and then communicated in real time to key fighting forces, will be essential in the war to eradicate terrorism.

Using microsystems, nanotechnology, and advanced materials, we are researching the concept of constructing satellites about the size of a volleyball (or smaller) that could have the capabilities of today's minivan-sized satellites. Smaller satellites require less power and are less costly to launch.

Using our radiation-hardening expertise, we are building space-qualified computers that are two generations ahead of those currently in use. We also are developing instruments, both for satellites and test vehicles, which are smaller, faster, and more reliable than today's instruments.

Sandia has demonstrated its operational data fusion, modeling and simulation, and advanced sensor capabilities for remote sensing. Examples include proven or developing capabilities to:

- use the Altus unmanned aerial vehicle as the platform for a standoff light detection and ranging (lidar), developed to detect WMD proliferation effluents. The aircraft recently completed a successful engineering flight test deployment at the Dugway Proving Grounds in Utah, with a payload that consisted of all flight components with the exception of the laser and detector subsystems. The flight series with the operational lidar is scheduled for May 2002.
- perform detailed mathematical and statistical analyses of more than 20,000 sensor events in a test sponsored by the Air Force Space and Missile Systems Center.
- use an improved method to evaluate the performance of an intersatellite communications system used by Global Positioning System (GPS) satellites. This work influenced the design of future GPS satellites.

The Altus unmanned aerial vehicle.

PHYSICAL SECURITY/SURETY FOR OUR NATION

Protecting the Nation's Vital Assets

Sandia is the National Nuclear Security Administration's (NNSA) lead laboratory for physical security. We have developed technical capabilities in security modeling and systems analysis, security equipment and components, and security systems engineering, integration, and implementation. We provide innovative and effective solutions to protect nuclear assets, and we are adapting our physical security technologies to protect other assets, enhance the security of our citizens, and mitigate terrorism and crime.

The research challenges include advanced sensor systems, increased modeling of security system effectiveness, and architectural surety technologies.

Project leader Heidi Smartt demonstrates remote monitoring technology designed to keep an eye on nuclear materials in storage or in use around the world.

We have developed technologies and systems to support:

- advanced explosives detection at airports and other sensitive facilities
- three-dimensional video motion detection
- flightline security enhancements using color video and thermal imagers
- methodologies for assessing the security of river dams and municipal water supplies
- armed, mobile, robotic platforms

Recent program advances focus on detection and disablement technologies for devices that could be used as weapons, including standoff detection and disablement of truck bombs, such as the one used in Oklahoma City. The commercial Hound™, derived from the explosives detection portal technology research program sponsored by DOE's Office of Security, was developed for the Federal Aviation Administration and is capable of detecting infinitesimally faint traces (parts per trillion) of explosives and other chemicals.

Other Sandia technologies developed for facilities protection include 3-D video motion detection; a system that combines color video with thermal imaging for enhanced flightline security; and a remote response platform that mounts various weapons on robotic vehicles.

Sandia is focusing its more than 30 years of experience in the design and development of security technologies for DOE facilities on two growing national concerns—school security and corrections technologies. The National School Security Technology Center, established at Sandia in 1999, continues to research technologies and systems for safer schools. The center conducts studies and workshops nationwide.

National expenditures for corrections have increased about eightfold in the past two decades. With close to 6.5 million adults incarcerated, paroled, on probation, or under supervision nationwide, costing $50 billion annually, more effective application of security technologies could provide substantial savings and increased safety for the nation's 350,000 corrections employees.

Researchers in Sandia's Security Systems and Technology Center are applying their nuclear security skills to the challenges faced by U.S. prisons—keeping prisoners secure and safe and keeping contraband out.

INTELLIGENCE

Using Our Technologies and Expertise to Analyze Information

Sandia's strong multidisciplinary expertise has led to the development of many world-class technologies that

provide the nation with solutions to new challenges. Sandia's diverse technical base and its ability to focus on emerging technologies allow it to address nationally significant and technically relevant intelligence issues.

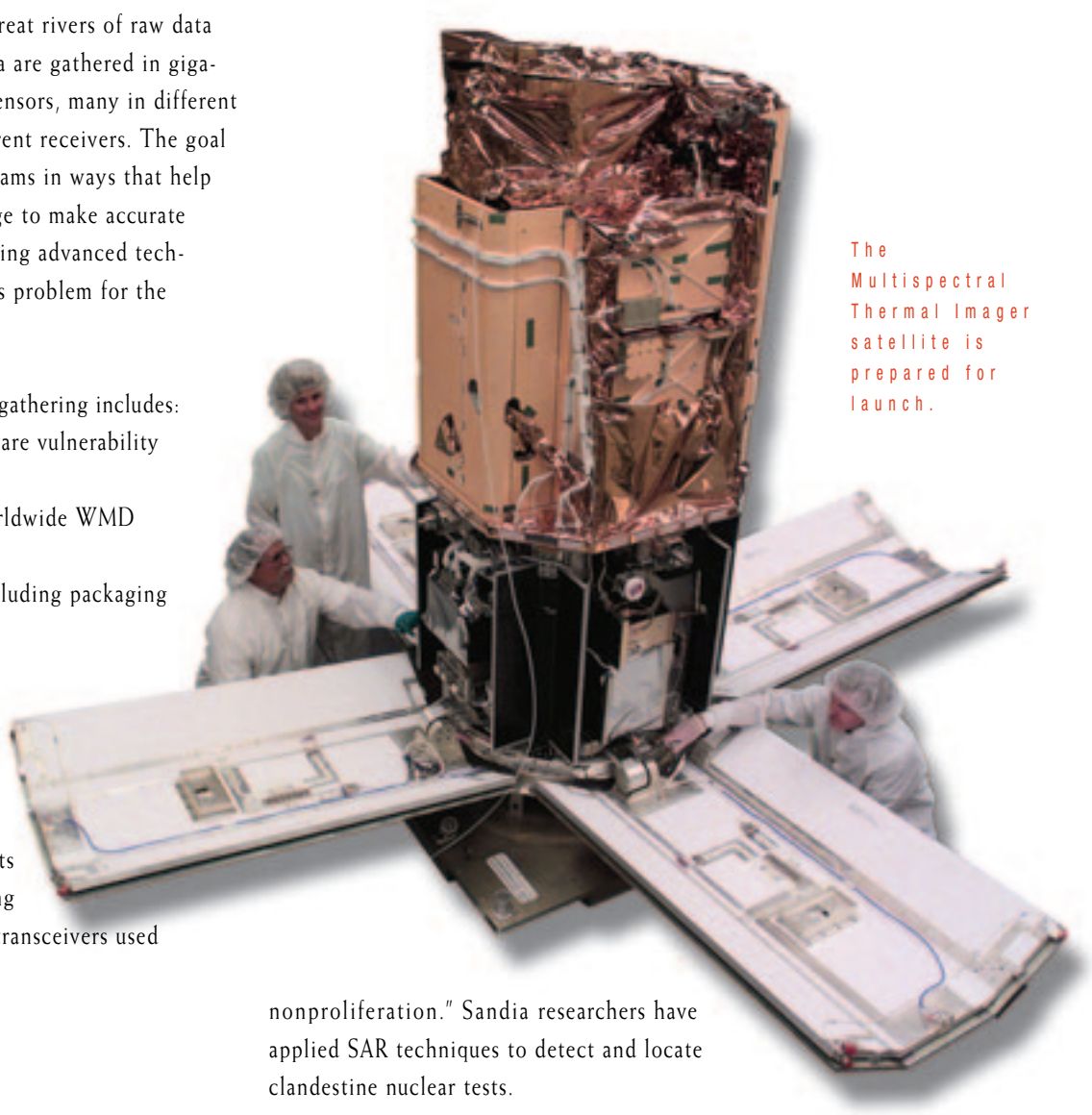
For decades the grand challenge of the intelligence community has been to reduce great rivers of raw data into streams of information. Data are gathered in gigabits per second from countless sensors, many in different formats, communicating to different receivers. The goal is to sieve these information streams in ways that help analysts gain sufficient knowledge to make accurate decisions. Today we are researching advanced techniques that may help address this problem for the intelligence community.

Sandia's expertise in intelligence gathering includes:

- software, firmware, and hardware vulnerability assessments
- proliferation analyses and worldwide WMD weaponization analysis
- sensor system development, including packaging
- nuclear data analysis
- materials science
- MicroElectoMechanical Systems research
- secure communication
- radar hardware and telemetry
- foreign technology assessments
- activity and facility monitoring
- tags (small, battery-powered transceivers used for monitoring)
- target characterization
- satellite systems engineering
- miniaturization technologies
- photonics

An aircraft works in concert with a satellite to provide remote sensing information to fighting forces.

Synthetic aperture radar (SAR) imaging, used for arms control, nonproliferation, and other national security issues, has been acknowledged by both NNSA and Congressional leadership as "critical to national security activities in weapons systems, arms control, and nuclear nonproliferation." Sandia researchers have applied SAR techniques to detect and locate clandestine nuclear tests.



The Multispectral Thermal Imager satellite is prepared for launch.

INTERNATIONAL SECURITY

Raising the Technological Barriers

Sandia develops technologies and systems to counter the increasing nuclear dangers of the post-Cold War era. For decades, the design and manufacture of a nuclear weapon has been well within the grasp of an industrialized society.

Kent Biringer, center, of Sandia's Cooperative Monitoring Center, shows Nazir Kamal, left, an international relations expert from Pakistan, and Pravin Sawhney, a journalist and former army major from India, a model of a nuclear missile being transported.

The biggest barrier has been obtaining weapons materials. Sandia develops technologies and processes at a time when international borders have loosened and the availability of advanced weapon design, production, and deception technologies has increased.

Sandians are working with the Trilateral Initiative of the United States, Russian Federation, and the International Atomic Energy Agency to develop a model verification agreement and explore verification technologies.

Sandia's Cooperative Monitoring Center (CMC) is a microcosm of our international security efforts. The CMC was established in 1994 to develop monitoring technologies and to provide a forum for nations to develop and implement cooperative solutions to shared problems—all with the intent of improving regional stability. In one instance, Sandia is collaborating with nuclear physics institutes in Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan in a waterborne radionuclide monitoring experiment on the major rivers in Central Asia. This cooperative experiment enhances regional security and promotes nuclear nonproliferation. A similar project involved India, Pakistan, Nepal, Bangladesh, and Sri Lanka. Scientist-to-scientist interactions such as these help to forge transnational bonds that reduce regional conflicts.

Helping Russia by Sharing our Security Technologies

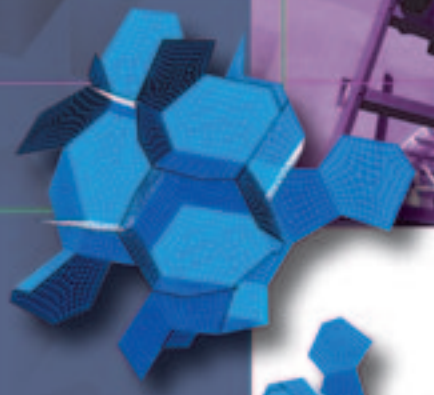
Sandia is the world's treasury of knowledge for nuclear security, having been charged for many decades with

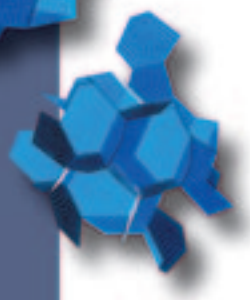
developing and implementing security for the entire U.S. weapons complex. We share technologies for protecting our nuclear arsenal with Russia in a program that complements our support of the nation's policies on international nonproliferation. The theft or diversion of even a few kilograms of weapons-grade materials is a major concern.

The dramatic breakup of the Soviet Union poses a continuing proliferation threat for these nuclear assets. For decades, Russia relied on a "guns and guards" approach to security. For the past nine years, Sandia and the DOE (now NNSA) have helped Russia develop a more rigorous systems approach to protection of these assets. Two recent examples are:

- The Mayak Production Association, which consists of numerous plants that process and store large quantities of plutonium and uranium for both weapon and civilian uses. Under the sponsorship of the DOE Material Protection, Control, and Accounting (MPC&A) Program, Sandia provided the Mayak Project with an initial design for heavy steel-clad, steel-reinforced concrete covers to deter illicit access to the materials.
- Russia's nuclear cities face many hardships, which can be mitigated with enlarged commercial and civilian ventures. For example, a Russian institute's research project is taking advantage of advances in sensors, materials science, and microcomputers to develop an artificial limb that more closely emulates the living leg in terms of both performance and comfort. This effort employs 120 Russian scientists from a formerly closed city.

Russian scientists visit Sandia's Microelectronics Development Laboratory.





From top: Sandia's µChemLab/CB™; members of Sandia's Rescue and Recon Team; Sandia's hopping robot; finite element model of a low-density closed-cell foam.

Countering Threats *to the Nation*

Sandia National Laboratories has been working to maintain national technological superiority in weapons systems since its founding more than 50 years ago. This superiority will be critical in the lengthy and difficult campaign to eradicate terrorism. Sandia is aware that national preparedness depends in part on increasing both the depth and scope of our technology-based defenses.

As the terrorist attacks of September 11th only begin to indicate, the potential for asymmetrical warfare, including the use of chemical, biological, nuclear, and information weapons, poses greater threats than ever to America and nations around the world. But advanced technologies can detect, locate, characterize, defend against, and if necessary, destroy such threats. Sandia is working hard to develop these technologies.

The span of Sandia's work in helping our nation secure a peaceful and free world through technology is extraordinary, not just in this nation, but worldwide. From basic research to global intelligence, our mission supports many agencies in an effort to combat proliferation, attempts at regional supremacy, terrorism, and threats against our armed forces and homeland.

Jim Tegnelia,
Vice President
Department of Defense Programs

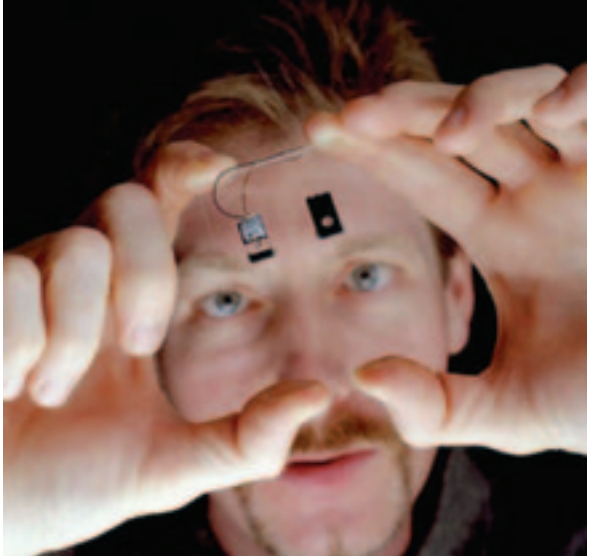
FIELDING NEW SYSTEMS FOR COUNTERING TERRORISM

Sandia develops new technologies for national security and plays a leading role in working with industry and government agencies to field tools and systems that are in use today. From simple but effective decontamination foams to worldwide systems for locating hard-to-find threats, Sandia technologies help protect America as it defines its future warfighting and homeland defense strategies.

A Basic Defense: Decontamination Foam

Biological and chemical agents, whether engineered as weapons or accidentally released as at Bhopal, India, in 1984, are the worst nightmares for emergency planners. In addition to thousands of naturally toxic compounds, there are others specifically engineered as nerve gases and blister agents. Maintaining a stockpile of thousands of individual neutralizers and antidotes, and then deploying the correct ones quickly and without causing more harm, are seemingly impossible goals.

In response, Sandia has developed a single decontamination foam that has rendered all typical chemical and biological agents harmless. Remarkably, the foam's basic ingredients come from household ingredients such as hair conditioner and toothpaste, and are nontoxic after they have been mixed. The foam can be sprayed quickly over wide areas. Sandia engineered the foam so that it will stick to vertical surfaces and maintain its bulk until washed away.



Scott Ferko inspects a sensor that is part of Sandia's µChemLab/CB™, a handheld chemical-analysis system that can quickly analyze minute concentrations of chemicals.

In tests at Dugway Proving Ground, Utah, Sandia's decontamination foam scored first among 20 others against chemical agents, and tied for first among eight others attacking biological agents. Sandia's foam had two distinct advantages—it was the only one used against both types of agents and, unlike all others, it required no environmental assessment prior to use.

Sandia has licensed the foam technology to a number of commercial firms. The foam was on hand in case of an emergency at one of the 2000 presidential debates and at one of the political conventions. Small systems that look like a twin-canister fire extinguisher are already being sold for $29.95 and could well become standard issue for police, fire, and emergency vehicles.

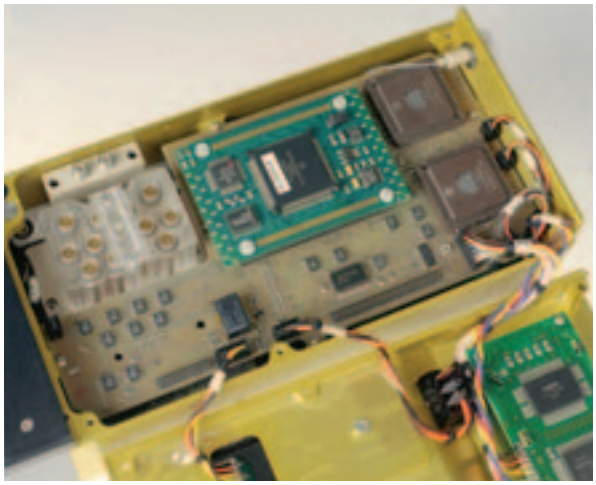
Stand off Chemical and Biological Detection

Over the past 90 years, chemical and biological agents have been released many times accidentally and intentionally on the battlefield and among civilian populations around the world. Industrial accidents involving these agents have far outnumbered acts of terrorism and have ranged from a single slightly sickened worker to blasts of poisonous gases that have annihilated neighborhoods.

Sandia's all-in-one decontaminating foam soon may be the best first response available in the event of a chem/bio attack.

The ability to rapidly identify a dangerous compound from a distance has considerable benefits for responders in small accidents as well as those helping in regional catastrophes. Too often, first responders lack the proper instruments and training, and can become victims themselves.

One of the "grand challenges" posed to DOE national laboratories is fielding a handheld system equivalent to a fully staffed analytical laboratory. Sandia's µChemLab/CB™ (Chem/Bio) has successfully passed tests for a number of chemical and biological agents and against common interferents, substances that block detection of the harmful agents. The µChemLab/CB™ uses an array of microtechnologies such as filters, piping, and detectors that are molecularly sized or engineered. In the hands of a first responder, it will identify which among thousands of substances might be present in the air or water.



Sandia's µChemLab/CB™.

But even the µChemLab/CB™ has limitations, particularly if an environment is too hazardous for humans, or if it would take too long to deploy on-site instruments. In response, Sandia has demonstrated standoff detection, or detection from a distance.

Stand-off technology is used in the Polychromator™, a microsystems-based technology that could be built into a soldier's binoculars to safely allow him or her to detect from several miles away whether a gas on the battlefield is potentially deadly. Through an innovative series of fast micromechanical and physics-based steps, the Polychromator™ sorts through millions of possibilities and identifies the

This computer image simulates a soldier on a battlefield looking at a gas cloud through a pair of binoculars containing the Polychromator™.

compounds in the gas. That information could be displayed in the binoculars and transmitted to command stations. Every step of the system has been demonstrated except for movable microsystems-based spectral gratings—a Sandia microtechnology that is currently being adapted.

The Polychromator™ is only one of a number of technologies that Sandia has developed in stand off detection. For instance, light detection and ranging (lidar) systems use scanning methods to sweep a landscape and characterize the substances in atmospheric plumes. Nonscanning systems provide near real-time ranging and other information. NASA used a Sandia nonscanning system to verify that the solar panels of the International Space Station were correctly deployed.

Other new sensors are based on technologies such as surface acoustic waves and fiber optics for chemicals, quartz resonators for fluids, and electrical or gravity field differences—all of which use microsystems.

Turning Robotics Outside In— The SMART Approach to Handling Explosive Devices

Until just a few years ago, bomb squads disposed of most devices by removing them to a remote or protected location and setting them off. But just moving a device, even if possible, was incredibly dangerous. Now bomb squads have a host of new tools—and extensive training to handle bombs in new ways—developed from Sandia technologies.

Pablo Garcia

Building the Perfect Robot

When Pablo Garcia gives a presentation, his favorite opening line is "What do weapons, cows, and eye surgery have in common?" Audiences are invariably baffled. The correct answer? Robotics.

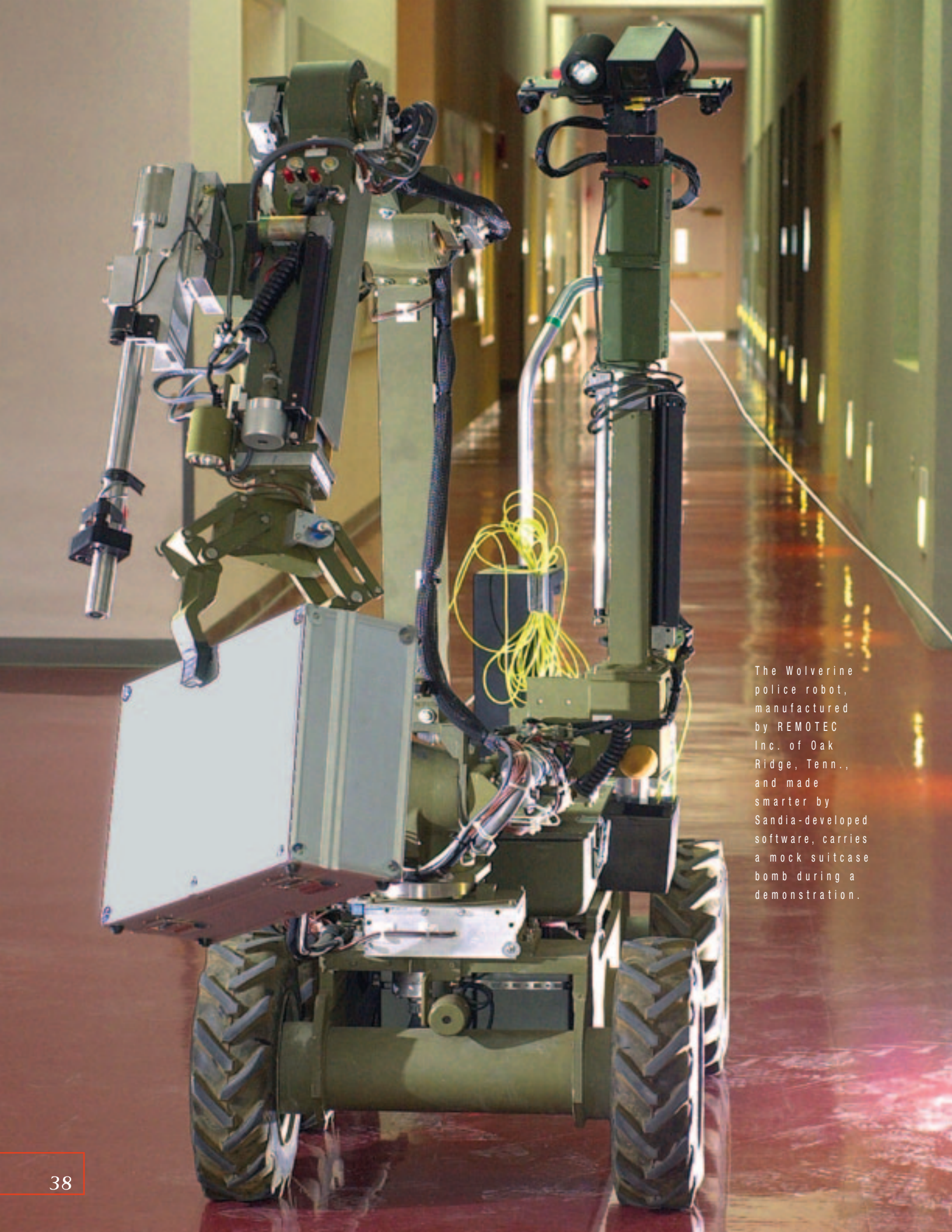
Diversity of applications is part of the challenge and thrill of working in the field of robotics and intelligent machines, Pablo says. As Deputy Director of Sandia's Intelligent Systems and Robotics Center, he may stop by a meat-packing company one day, and on the next view F-22 manufacturing activities. Subsequent days may include visits to a U.S. Army installation or a hazardous-waste site.

Robotics are ideal for conducting work that requires precision and repetition, or for performing tasks that are dangerous for humans. Robots don't get bored assembling products in high-volume or high-stress production lines, nor are they intimidated by disassembling aging munitions or handling toxic waste.

So far, no application has been too small or too large for Sandia robotics technology to tackle. But when a big job comes along, the systems have to be scaled up and Pablo must arrange a substantial budget. "We can easily be talking $6 million for a big turnkey system," he says. Pablo says robotic-system design for disassembling aging weaponry is one of the most critical tasks he has managed. Robotic systems are proving to be invaluable tools for helping the U.S. Army disarm 100 tons of munitions annually.

"Munitions were never intended to be dismantled," he says. "I'm hoping that what our technologists are learning about how to take munitions apart will be passed along to the weapon designers and that they will keep disassembly in mind as they design the next generation of weapons."

Yet when Pablo sees a machine doing a hazardous job, he becomes excited. "That's real work being done," he says.



The Wolverine police robot, manufactured by REMOTEC Inc. of Oak Ridge, Tenn., and made smarter by Sandia-developed software, carries a mock suitcase bomb during a demonstration.

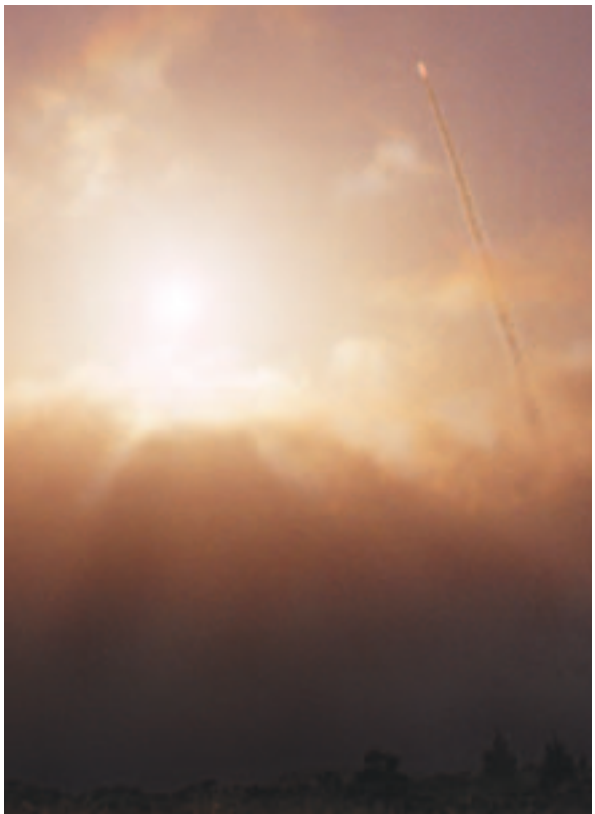
Sandia's bomb disablement systems, such as the PAN Disrupter™, are used to disable explosive devices by defeating the physics of an explosion. Sandia has developed techniques and systems to identify, characterize, and potentially disrupt bombs from a distance in a wide variety of situations.

Sandia now is combining bomb disablement with robotics. For instance, imagine a small robotic vehicle as it approaches a pipe bomb. A remote operator looking at images transmitted from video cameras mounted on the vehicle assesses the situation. Can the bomb be disabled in place? Does it have to be moved? What's the best sequence to perform either task? What tools are needed?

In the early 1990s, Sandia started on a radically different analysis of how fully automated systems and components could operate together, and where a human might be needed to intervene. These analyses produced two related software packages—SMART, the Sequential Modular Architecture for Robotics and Teleoperation; and Umbra, a simulation environment with capabilities for describing and controlling multiple robots, and incorporating weather, terrain, and radio-frequency interference modules.

SMART consists of modules for more than 300 robotic instruments and controls, all of which can be put together on a computer screen like assembling LEGO building pieces. The system then generates the computer programs to operate the custom assembly. Working throughout the modules are robotic functions such as coordinated motion, collision avoidance, video targeting, and automatic orientation, as well as basic robotics rules for movement.

Sandia evaluated a highly precise remote-operations weapons platform for Department of Energy security applications.



DEVELOPING TECHNOLOGIES FOR ASYMMETRICAL WARFARE AND HOMELAND SECURITY

Ballistic Missile Defense System

Because Sandia designed many of the elements of the nation's nuclear stockpile, it possesses a vast storehouse of knowledge about warhead flight characteristics and various signatures and behaviors. Further, our five-decade role in national security assessments gives us considerable knowledge of adversaries' designs and potential capabilities. Today, Sandia uses this knowledge to design and build realistic targets for National Missile Defense tests. This work includes development of smart, instrumented targets, modeling and simulation of lethality effects, and technologies associated with countermeasures.

Sandia is contributing to the development of a National Missile Defense by preparing targets that test the ability of interceptors to recognize and engage reentry vehicles in the presence of other objects.

Difficult Targets

Sandia is developing a range of technologies and capabilities to defeat difficult targets. Difficult targets include hardened, deeply buried underground facilities used to manufacture or store weapons of mass destruction, movable targets such as Scud missile launchers, and small incoming warheads from theater or strategic missile systems. These countering technologies must provide fast, often real-time, and overwhelmingly effective responses to complex and diverse early indications of potentially catastrophic threats.

Synthetic Aperture Radar

Clouds, haze, smoke, and even smog can blind many airborne surveillance systems. Nighttime poses its own problems, requiring the use of systems with less resolution. Sandia's small, high-resolution synthetic aperture radars (SAR) now provide all-weather, around-the-clock surveillance with 3-D capabilities.

Sandia has reduced the size of SARs so that small, unmanned aerial vehicles (UAVs) can easily carry them. Current UAVs are about halfway between the size of a large model airplane and a small private plane, and can fly at altitudes of about 60,000 feet for up to three days. Hovering above a battlefield, Sandia SARs can provide 3-D field terrain maps in minutes. Instead of trying to interpret terrain lines on a flat map, these maps, produced on a rubberlike material, give field commanders an immediate visual representation of obstacles.

A DeHavilland DHC-6 Twin Otter aircraft flies over a military vehicle on the plains east of Albuquerque during a test of a sophisticated Sandia-developed synthetic aperture radar (SAR).

U.S. Army Maj. Gen. Joseph Bergantz, center, is briefed on Sandia's Apache helicopter retrofit support program by Jim Tegnelia, vice president for Department of Defense Programs, left, and Bob Cantwell, manager of Sandia's Systems Reliability Department and Apache program manager.

Directed Energy Weapons

Imagine a bullet that travels at the speed of light, has a range of several hundred miles or more, and still packs enough of a wallop to disintegrate a half-ton, hardened warhead traveling at 18,000 mph. Realizing that feat is the goal of the U.S. Air Force Airborne Laser project.

Sandia is contributing key concepts, materials, and expertise to this and other directed-energy projects. We are applying our engineering expertise to the development of adaptive optics to correct for atmospheric distortions, to lasers with pulses in the 50-femtosecond range (the pulse is 0.15 millimeters in length), and to the need to fuse and manage, in real time, the vast amounts of targeting and guidance data.

Sandia is developing strategic wide-band technologies that will disrupt an adversary's total communications system, and narrow-band technologies to disrupt specific data channels. Coupled with Sandia technologies for spoofing and anti-spoofing—deceiving an adversary's systems and defeating attempts to deceive our own—these systems will give the nation new weapons and defenses for future warfare.

Sandia is helping to develop nonlethal systems that use microwave or laser technologies that will replace tear gas in dispersing riotous crowds or delay attacks on sensitive facilities. A microwave system that produces the sensation, and only the sensation, of intense burning at a range of several hundred yards, has already been demonstrated. While causing no permanent damage, the sensation, according to one volunteer, "is something that you only want to experience once in your lifetime."

Swarm Behavior—or Collective Intelligence

One would hardly consider an ant or a bee as being able to develop a logical, systematic approach to a problem. Yet these insects have highly sophisticated communications and tasking capabilities to find and transport food and to defend their nests.

At Sandia, we are applying this swarm behavior to robotic vehicles equipped with a wide array of manipulators and weapons. We integrate sensors, computers, and hardware to make highly refined systems that are able to collaboratively carry out highly complex tasks.

Not only must the sensors and instruments collect and process data while operating in an unstructured environment, but the swarm must be able to communicate and then make decisions about how best to accomplish its mission. The collective decision sometimes is to call in a person to make a decision.

Sandia has demonstrated swarm behavior—actually swarm intelligence—in unstructured environments. This includes the uses of mobile robots to guard a perimeter, intercept an intruder, search a building or a warehouse for intruders or harmful substances, and find skiers buried in an avalanche.

Robotics engineer Wendy Amai with a small swarm of Sandia's mini-RATLER robots.

Doug Adkins takes a close-up view of the minirobots he and Sandian Ed Heller are developing. At 1/4 cubic inch and weighing less than an ounce, they are possibly the smallest autonomous, untethered robots ever created.

Information Security

Exactly when is a system secure against credible threats? The answer requires a thorough knowledge of the system's strengths and weaknesses.

Over the past two years, Sandia's Information Design Assurance Red Team (IDART) has successfully compromised 35 out of 35 information systems. The team surmounted traditional defenses such as passwords, firewalls, filters, activity monitoring, and traps, and eventually found an avenue or method to compromise each system.

Although that accomplishment might cause alarm, Sandia has used the work to bolster the security of our nation's information systems. Using the cross-disciplinary approach that is characteristic of many of our discoveries, Sandia scientists theorized a computer defense system that would behave like the human immunological system, and then developed it.

These software agents, much like white blood cells patrolling our vascular network, are native to the system, so they know when events are normal and passing entities are doing gainful work. But once an agent detects an intruder or something going wrong, not only does the agent attack the intruder, it also immediately sounds the alarm to attract the aid of other agents. The agents are able to tailor themselves to defend against any intruder. In each case the result is the same: the intruder or unexpected event is immediately isolated and flagged, and its links to any computer process are cut off.

MEETING THE LOGISTICS AND DEMILITARIZATION CHALLENGES

The Department of Defense has set an ambitious goal of reducing logistics costs by about $20 billion over the next few years. Achieving this goal will require revolutionary new technologies and systems to build, supply, maintain, repair, and eventually retire our defense assets.

Robotics at Work: Painting the Stealth

U.S. F-117A Nighthawks swoop largely undetected through today's most advanced radars because of their angular exterior and "radar-invisible" paint, which minimize reflected signals. Over the next few years, the fleet of Nighthawks will be refurbished, which includes removing the aging thin films and coatings and replacing them with

Sandia developed a robotic paint system with Lockheed Martin Aeronautics Systems for the U.S. F-117A Nighthawk.

a radar-absorbent paint that is easier and less expensive to apply and maintain.

Sandia is using robotics to paint the Nighthawk, saving both time and money and improving the final finish quality. Using a commercially available robot, Sandia developed and applied a unique path-planning system that tells the system to adjust for differences from aircraft to aircraft. Path planning is one result of Sandia's years of research in "geometric reasoning," developed with DOE Defense Programs and lab-directed research funding.

It took five painters and a masking crew 4.5 days to paint the first Nighthawk. Using the robotic technology, a smaller crew took only three days to paint a subsequent Nighthawk.

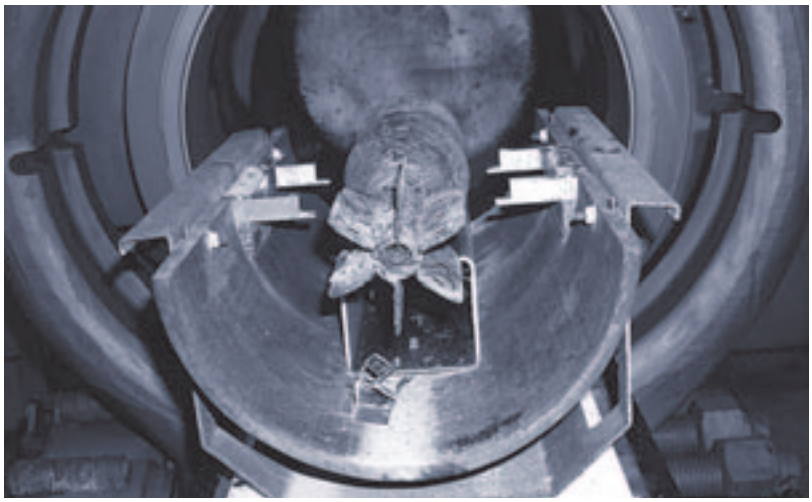
Demilitarization

A Sandia system that uses supercritical water oxidation—essentially superheated, superpressurized water—is destroying munitions that could cause environmental damage if simply detonated. The wastes are destroyed within seconds, producing such harmless commonplace end products as carbon dioxide, water, and salts.

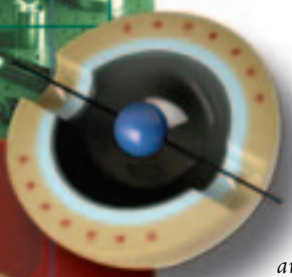
Sandia's Explosive Destruction System successfully destroyed six "bomblets" that contained sarin nerve gas. The bomblets were found during the cleanup of the old Rocky Mountain Arsenal near Denver, Colo.

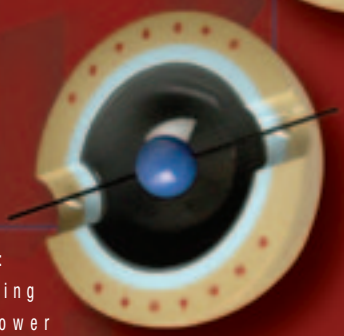
Top: A U.S. Army ordnance expert uses protective gear and a long pole to load sarin-filled bomblets into the Explosive Destruction System at Rocky Mountain Arsenal.

Sandia has joined the worldwide demilitarization effort to rid the globe of landmines. Sandia's work in landmine detection and demining ranges from laying down a quick-hardening foam in order to clear a path for military vehicles, to chemical sensing in order to restore larger areas to their prewar status.



Bottom: This mortar shell was one of 30 destroyed by the EDS during testing at Porton Down in the United Kingdom.





From top: Dish/Stirling remote power system; wind turbine; laser at the Combustion Research Facility; cutaway models of what magnetically insulated fission electrical cells might look like.

Energy and Critical Infrastructures

Sandia provides solutions to the complex problems of supplying the nation with secure, clean, abundant, and affordable energy and water.

The attacks of September 11 put greater emphasis on our programs to protect the nation's infrastructure. We began this effort five years ago by focusing on cyberthreats to energy supply systems. Laboratory Directed Research and Development (LDRD) played a key role in developing a technology base to address cyberthreats by understanding interdependencies in our energy system and developing countermeasures. Several federal agencies are now expanding that work.

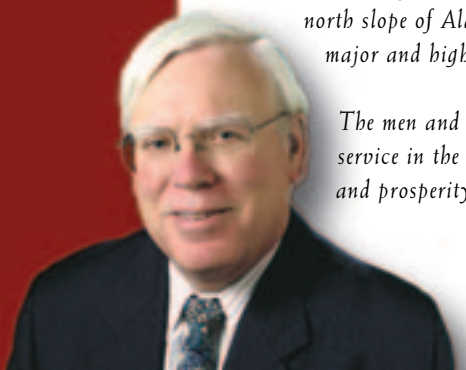
Over the past two years, we have applied LDRD to research issues related to water safety, security, and sustainability, based on the realization that scarce water is a basis for conflict in the Middle East. Within the United States, water supplies are vulnerable to attack. We now work with federal, state, and metropolitan agencies to increase the security of water systems.

Sandia's work in nuclear reactor safety, in improving supervisory control and data acquisition systems, in airliner safety and air traffic control systems, and in information security will continue to support our long-term goal of national and eventual worldwide prosperity while placing greater emphasis on security. These are just a few examples of the scope of our work in protecting our energy supplies and critical infrastructures.

The scope of research and development ranges from fundamental research sponsored by the Department of Energy (DOE) Office of Science to large-scale tests supported by U.S. and foreign governments. We believe that much of the research to enhance security will also improve the environment. Our vision of "zero emissions" power generation and transportation by 2020 is perfectly complementary with decreasing our dependence on oil from the Middle East. We are committed to providing a holistic systematic approach to energy issues facing the country.

In addition to Sandia's two main laboratory sites, we have operations in Carlsbad, N.M.; Las Vegas, Nev.; and smaller numbers of people in Hanford, Wash.; and the north slope of Alaska. The Combustion Research Facility in California is a major and highly successful DOE collaborative research center.

The men and women who perform the work in this area render exceptional service in the national interest by providing secure, clean power for peace and prosperity.



Bob Eagan
Vice President
Energy, Information & Infrastructure Surety

CLEAN POWER FOR PEACE AND PROSPERITY

National Security through Plentiful Energy and Water

America's national security depends on efficient, reliable energy and an abundant supply of fresh water. The generation and delivery of these resources require a vast interrelated network of circuits, wires and cables, pipelines, information, and services—all part of the nation's critical infrastructures, which are now under potential terrorist attack. Energy supplies from abroad are now more susceptible to disruption, and our energy distribution system may well be subject to increased attacks.

Sandia develops technologies and the expertise to ensure those infrastructures remain secure and reliable. While these efforts cannot supplant vigilance and intelligence, they can provide increased means of detection, countermeasures, and mitigation.

Sandia is developing technologies that will help protect America's energy infrastructure, including its electrical power grid.

We also help industry develop more efficient means of producing energy and of extracting fossil fuels from the ground. Sandia's work targets the four stages of the energy cycle: production, distribution, consumption, and recycling or disposal.

David Holcomb takes a close look at the disposable fiber optics he developed to relay information about what is going on at the end of a drill string while the drilling operation is in progress.

Production

Sandia is developing technologies to boost production of multiple types of energy, including hydroelectric, geothermal and solar power, and nuclear fission and fusion. Much of our work is focused on helping the oil industry with reservoir management practices, particularly as drilling reaches deeper and deeper to tap new gas and oil deposits. One difficulty is borehole damage caused by compacted rock in areas such as California's diatomite fields. Reservoirs in these fields are particularly susceptible to compaction due to diatomite's high porosity. Well replacement, lost production, and abandonment costs in these reservoirs alone have exceeded a total of $200 million.

Funded by the Department of Energy (DOE), Chevron, and Aera Energy, Sandia scientists have developed computer modeling and simulation techniques to predict and analyze the impact of various well-drilling patterns and water flooding on the integrity of wells situated in the chalklike diatomite fields. Sandia's industry partners have incorporated these recommendations into their reservoir-management practices.

DOE-funded solar thermal system development, integration, and testing projects have culminated in the installation of our first working Dish/Stirling solar power generating system. Sandia delivered the system to Laguna Pueblo in New Mexico, where it is supplementing diesel engine power. Dish/Stirling solar power systems have the potential of allowing rural America to replace conventional polluting energy generation sources with clean energy.

A National Academy of Sciences report released in 2001 stated that the DOE's investment of approximately $13 billion in energy efficiency, coal, and other fossil fuel

Sandia student intern Jasmin Arzate looks at a Dish/Stirling remote power system.

Large-scale experimental tests at Sandia have included the high-speed crash of an F-4 fighter plane into a concrete wall that modeled a containment vessel.

research programs since 1978 had yielded returns of about $40 billion. The report noted the work Sandia and General Electric did to improve the design of the polycrystalline diamond compact drilling bit. "Penetration rates were three to five times faster than with conventional diamond bits," the report said. "Today these drill bits account for about one-third of the world-wide drill bit market and have sales of over $200 million per year."

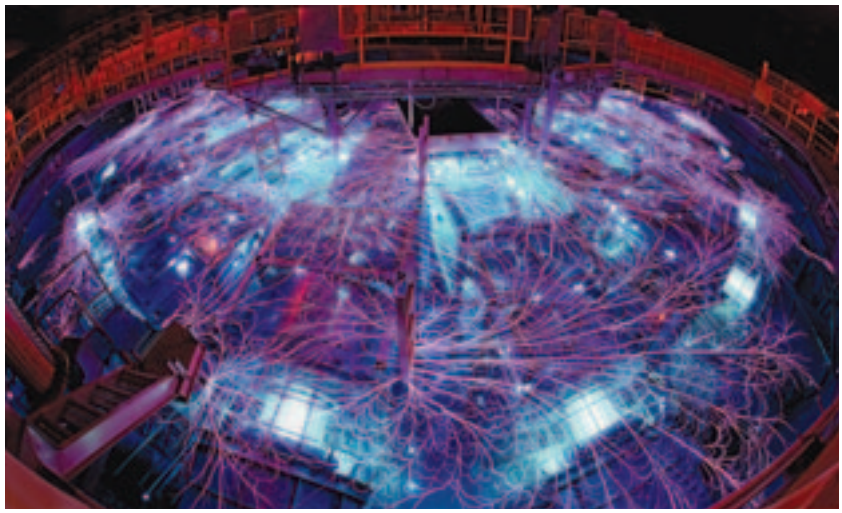
Nuclear energy accounts for about one-fifth of the nation's power production. The operational safety of existing power plants, and their vulnerability to attack, have long been areas of Sandia research and testing. Sandia's modeling and simulation of nuclear reactor operations and failure scenarios lead the world. Large-scale experimental tests in the past included the high-speed crashing of an F-4 fighter into a concrete wall that modeled a containment vessel, and the crashing of a 100-ton "runaway" locomotive into a truck carrying nuclear waste. These tests and others provided the basis for safety analyses of nuclear plants and transportation methods. This year researchers conducted a large-scale experiment in which a 1/4-scale model of a Japanese nuclear reactor's containment vessel was overpressurized to the point of failure. The results led to new benchmarks for structural analysis codes. The U.S. Nuclear Regulatory Commission and Japan's Nuclear Power Electric Company cosponsored the test.

The nation's dependence on imported oil from a region which may face increased political instability, as well as the finite supply of fossil energy, may lead the nation to re-examine nuclear energy. Sandia stands ready in two areas: safely extending the productive lives of existing nuclear plants, and designing new types of fission-based plants that produce less waste and materials that could be diverted into radiological or nuclear weapons.

Beyond fission is fusion, the power of the stars. Sandia's Z accelerator, which produces laboratory conditions that are close approximations to nuclear explosions, continues to provide critical experimental data for the stockpile stewardship program. For energy research, it is clear that the Z accelerator has pointed the way to future advances in controlled fusion. The Z accelerator produces more than 50 times the X-ray energy and five times more X-ray power than any other laboratory facility. Sandia has acquired funds to refurbish the Z accelerator to attain even higher energies.

While the path to fusion as an inexhaustible and inexpensive source of power is still long, recent experimental facilities and tests at Sandia help to confirm that our national efforts are headed in the right direction, rather than toward a dead-end tunnel. An example is refurbishment of the NOVA laser from Lawrence Livermore National Laboratory, once the most powerful laser in the world and a test-bed for the National Ignition Facility. Rebuilt and reconfigured at Sandia's Albuquerque facility at a fraction of the cost of a new diagnostic instrument, the renamed Z-Beamlet provided X-ray pictures that confirmed one essential element for fusion—the physical symmetry of

Sandia technologies, such as polychrystaline diamond compact drill bits, have increased penetration rates and duration of drilling activities. They also have saved lives by reducing hazardous activities associated with changing drill bits.



Sandia's Z accelerator, the most powerful producer of X-rays in the world.

Sandia researcher Jeffery Danneels has developed a program to study the vulnerabilities of water systems.

implosion of a fusion capsule. Previous experimental data detected asymmetrical fluxes in surrounding plasma fields and X-ray propagation, suggesting an unwanted asymmetrical implosion. Refining previous experimental data and confirming a symmetrical implosion are just the first steps in our expanded Z accelerator program.

Distribution

Sandia is developing a variety of technologies that help keep America's critical infrastructures secure and reliable. We assessed the management systems and security practices of the U.S. Bureau of Reclamation, the nation's second largest producer of hydroelectric power. The analysis led to the integration of the latest supervisory control and data acquisition technologies at six hydroelectric projects, including the Hoover, Shasta, and Grand Coulee dams. The assessment program is now in its second phase, providing similar input for five additional dam sites. About 10 percent of America's electricity needs are provided by hydroelectric power.

Over the past year and a half, Sandia researcher Jeffrey Danneels has worked with the Environmental Protection Agency (EPA) and the American Water Works Association Research Foundation developing a program to train water utilities to assess the vulnerabilities of their systems and to develop measures to reduce the risks and mitigate the consequences of terrorist or other criminal attacks. The program stems from a performance-based vulnerability assessment methodology initially developed by Sandia to support the national nuclear security mission. It has since been modified to evaluate the vulnerability to terrorist attack of government buildings, U.S. Air Force bases, nuclear power plants, nuclear processing facilities, prisons, and federal dams.

Standards and controls are vital to the predictable and secure flow of electrical power. Working closely with industry and utility standards boards, Sandia has made major contributions toward achieving highly effective, economical methods for connecting photovoltaic systems to utility grids. Our R&D programs have included technologies for automatically diverting or shutting down electricity flow from grid-connected systems when an electric distribution line shuts down—an important breakthrough that encourages the development of distributed energy systems.

Sandia researchers are developing information security practices to meet the next generation of Internet security threats. The research team developed Standard Agent Architecture II/Agent-in-a-box, which has brought revolutionary advances in agent and information security. The Advanced Information System Lab's (AISL) intelligent agents provide a dynamic defense for domains, a significant contribution to national security that also represents substantial commercial value for the multibillion-dollar cybersecurity industry.

Miriam and Duane Hilborn look at the photovoltaic system they use for electricity in their home on the Laguna Pueblo. They purchased the system from an Albuquerque manufacturer and obtained information on safety and installation from Sandia, which encourages the use of photovoltaic systems in remote areas.

Sandia is developing specifications for more secure control systems for distributed energy resources. Called SCADA, for supervisory control and data acquisition, the systems are used in many industries and are important for monitoring and controlling equipment on electric power systems. In a distributed energy network with a large number of energy generation and storage devices to control, the reliability and security of SCADA systems become more critical than in today's network. Sandia's SCADA researchers serve as advisors to national and international standards committees charged with developing security specifications for future SCADA systems.

Bob Green of the Engine Combustion and Hydrogen Department at Sandia's Combustion Research Facility in Livermore, Calif., examines a diesel engine.

Consumption

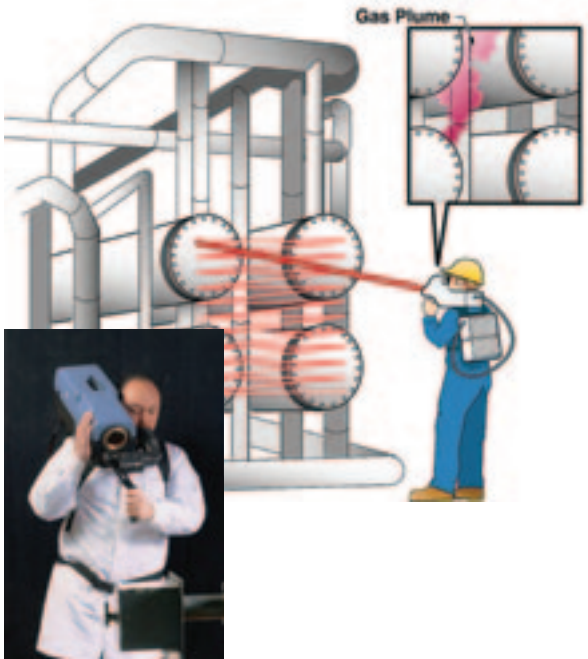
Sandia is striving to bolster the effective and efficient use of nuclear power and carbon fuel energy. We have gained great insight into diesel engine combustion dynamics. Although diesel fuel burns relatively efficiently, it creates soot. Sandia has identified diesel engine design factors that create soot and is applying that knowledge to next-generation diesel engine design. Research at Sandia's Combustion Research Facility in Livermore, Calif., has led to guarded optimism that particulate and NOx (nitrogen oxides) emissions can be reduced at the source without sacrificing fuel economy.

The island community of Metlakatla, Alaska, is enjoying a cleaner environment and stronger economy thanks to a Sandia-developed battery energy-storage system. The system has almost completely replaced a diesel system that necessitated the annual transportation of nearly 500,000 gallons of diesel fuel from the mainland by ferry and its subsequent piping across the island, presenting the potential for accidental spillage. Diesel emissions and noise have been greatly reduced and, at times, eliminated. The DOE-sponsored energy storage system was installed in 1997 and its $1.5 million cost was fully recovered within three years. Similar energy-storage systems, smaller in scope, protect energy-sensitive facilities from voltage spikes and sags and, by reducing energy-usage peaks, save millions of dollars in peak-usage surcharges for many users.

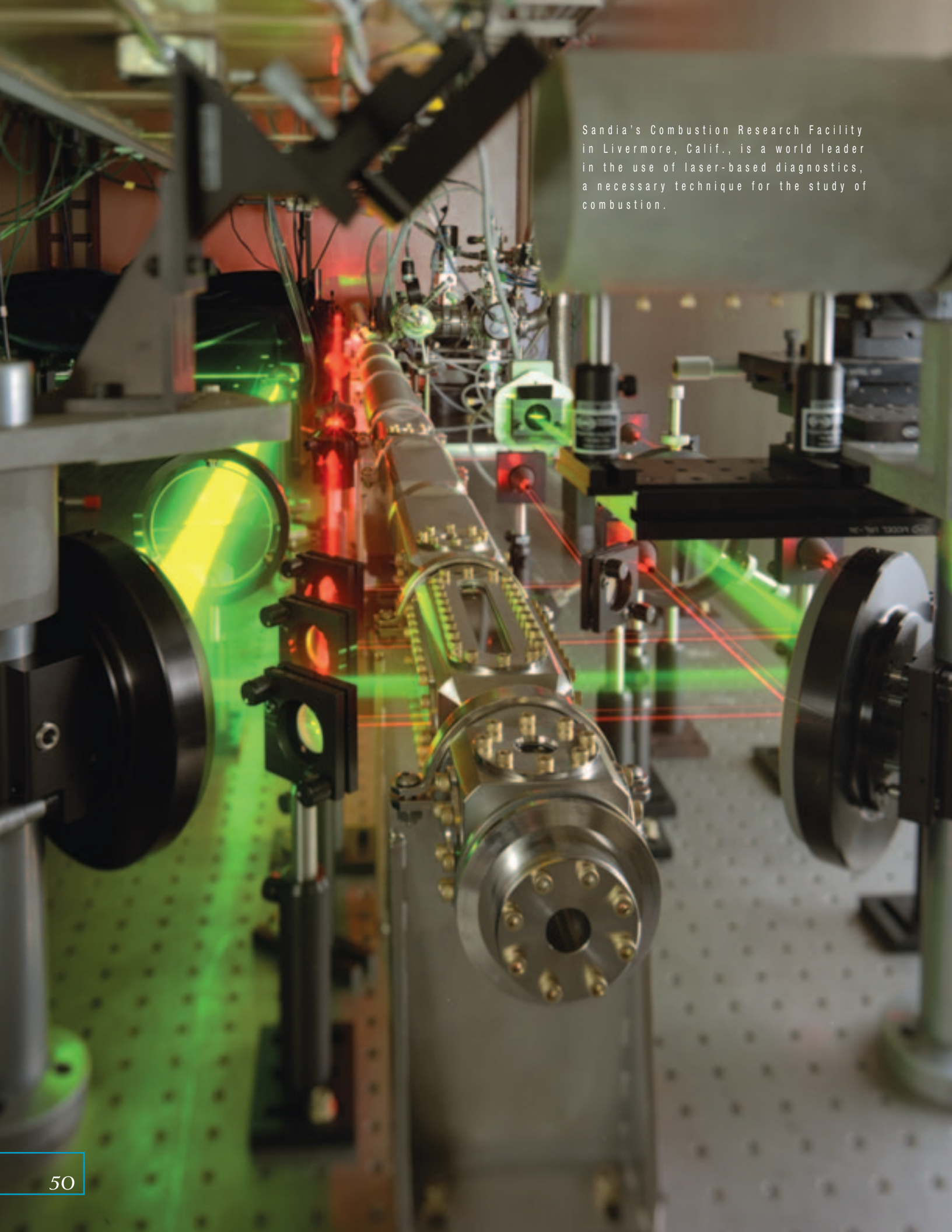
To help facilitate high-level energy and climate change policy discussions, Sandia developed laptop computer dynamic simulation models that link energy, the economy, and the environment. Current models for the United States and China project annual energy demand and carbon emissions out to 2020 and allow very rapid assessment of alternative economic, policy, and technology scenarios. The U.S. model has been widely shown and distributed, and has helped administration officials and congressional staff understand the complexity of energy policy and the difficulty of meeting the Kyoto Protocols.

Disposal and Recycling

A Sandia technology that detects hydrocarbon gas leaks at oil refineries promises to help cut down on greenhouse gases and smog. The portable video imager uses some of the newest optical materials and laser technology and will



Ricky Sommers demonstrates the portable video imager, used to detect hydrocarbon gas leaks at oil refineries.

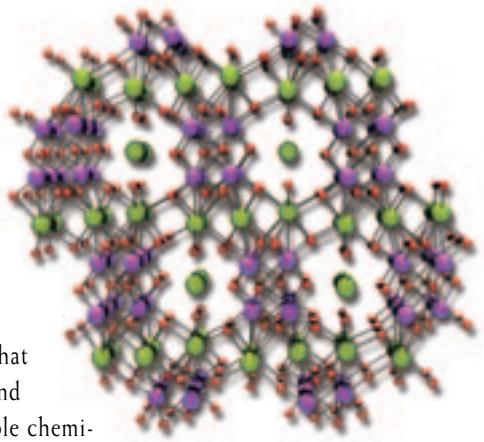


Sandia's Combustion Research Facility in Livermore, Calif., is a world leader in the use of laser-based diagnostics, a necessary technique for the study of combustion.

streamline industry's ability to achieve EPA regulatory compliance. Funded by the DOE Offices of Fossil Energy and Industrial Technology and the American Petroleum Institute, the new instrument will quickly check for leaky valves—detecting and identifying a range of hydrocarbons—at refineries and chemical plants. On the horizon, even newer engineered crystals could push the imager's operation into the long-wave infrared region, making it possible to detect more types of gases. Researchers are working on a backpack-sized system that will likely undergo refinery tests in late 2001.

In a NASA-funded project, a Combustion Research Facility research team has developed a sensor that uses ultraviolet laser-induced fluorescence to detect atmospheric SO^2. Fossil-fuel SO^2 emissions influence atmospheric chemistry, air quality, and climate on local, regional, and global scales. The highly sensitive instrument measures ambient SO^2 at the parts-per-trillion level. A compact field version of the sensor being constructed uses a single-mode fiber amplifier, a technology adapted from optical telecommunications.

Scientists in Sandia's environmental management science program discovered a family of tunnel-collapsing materials that are capable of trapping a variety of molecules, including the radioactive isotope strontium-90. Called Sandia octahedral molecular sieves (SOMS), the materials contain micropores that clean up industrial processes and waste streams, filter out valuable chemicals for reuse, and trap radioactive residues like those that accumulate inside the underground storage tanks used in nuclear weapon production.



Model of SOMS (octahedral molecular sieves), showing its framework and tunnels.

SOMS show promise for cleaning up the nation's worst environmental problem—53 million gallons of radioactive waste at DOE's Hanford, Wash., site. The waste is the byproduct of 50 years of nuclear weapons production. The new SOMS can be engineered at the atomic scale to be extremely selective for strontium-90, one of the two most prevalent radioisotopes in the Hanford tanks and extremely poisonous to humans. Normal strontium is an essential and plentiful mineral in vegetables and milk.

In tests, the SOMS trapped 99.8 percent of strontium-90 ions in parts-per-million concentrations from solutions containing chemically similar and highly abundant sodium ions. Because the SOMS are crystalline and inorganic, they stand up to the highly caustic environments found in the tanks. Furthermore, when heated to about 500°C, the strontium-saturated SOMS collapse into a dense glasslike material with a perovskite crystal structure, its shrunken pores locking the strontium tightly into its impervious crystalline structure.

Some radioactive wastes remain dangerous for thousands of years. The United States is isolating these high-level wastes in underground repositories. But before a repository can accept wastes for isolation, assessments of the facility's long-term performance must

Tina Nenoff examines vials of recently crystallized SOMS powder.

Melissa Douglas

The Joys of Discovery

Plasma physicist Melissa Douglas was in suspense when her experimental design for nuclear fusion—a configuration of tungsten wires one-tenth the diameter of a human hair—was put to the test in Sandia's Z accelerator. Immediately afterward, as she and colleagues reviewed the voltage profiles, she realized the test was a success. Formal data analysis revealed that the accelerator's surge of plasma power—lasting for a few billionths of a second—had produced X-ray energy 80 times greater than the entire electrical generation output of the world.

In essence, for that briefest moment, the accelerator reached a temperature of 1.8 million C, thereby creating a miniature sun and achieving a major step in the quest toward producing fusion. The breakthrough led to her being in demand for speaking engagements and was her entrée to the inner circle of plasma physicists.

One of few women to pursue a career in the extremely competitive field of plasma physics, Melissa quickly earned the respect of colleagues. In 1999, she received the Early Achievement Award of the Institute of Electrical and Electronics Engineers' Nuclear and Plasma Sciences Society. That same year, *Esquire* Magazine featured her in its annual spotlight on genius. But success had its drawbacks. "They (*Esquire*) portrayed me as some kind of workaholic who doesn't have a life," she laments.

Overall, however, she concedes the recognition was gratifying, although today her values have evolved. "I spent a lot of time trying to impress people in those days, but I eventually learned that my real joy lies in discovering and understanding the physics," she says. "Now I do the things I do because I enjoy them, and they also fit in nicely with Sandia's programs."

The Z accelerator's ongoing achievements are building a foundation for sustaining the nation's nuclear stockpile without actual tests. Sandia uses the Z accelerator to study the basic properties of matter at high temperature and density, the physics of inertial confinement fusion, and the survivability of hardware in the U.S. nuclear stockpile.

Melissa currently is working on eliminating potential plasma instabilities that may arise during controlled nuclear fusion, and she doesn't mind admitting that intuition has always been central to her experimental design process. "Most of the things I do in physics start with a feeling that has rarely been wrong," she says.

show a reasonable expectation that the repository will protect the health and safety of the public for many thousands of years. Sandia is helping to assess potential environmental contamination from radioactive wastes at several sites, including the Yucca Mountain in northwestern Nevada, and the Waste Isolation Pilot Plant (WIPP) in Carlsbad, N.M.

Sandia has developed new models for assessing future nuclear waste disposal risks, including the transporting of spent nuclear fuel. Our models have greatly improved the accuracy of the information available to decision makers and they likely will become the nation's standards.

Sandia was part of a collaborative team of 26 subcontractors, including four DOE laboratories and the U.S. Geological Survey, and numerous private companies, who contributed to the DOE's Yucca Mountain Draft Environmental Impact Statement (EIS). Our risk assessment recommendations have been included in the revised EIS, which recommends Yucca Mountain as a suitable disposal site for high-level radioactive waste from commercial power plant reactors and government defense programs. WIPP has been receiving transuranic radioactive waste since 1999. With geotechnical studies now completed, Sandia has shifted the focus to operational studies and is now engaged in ensuring that hazardous byproducts will be transported from the production sites to Carlsbad within the time frame specified contractually with DOE.

Water Safety, Security, and Sustainability

The demand for reliable and sustainable access to fresh water in the United States is fast outpacing supply. Water is becoming an increasingly precious commodity. Sandia's water management initiative seeks solutions to the challenges facing our nation's water infrastructure—challenges of scarcity, systems vulnerability, and the economics of supplying drinkable water. The initiative focuses on monitoring water quality, assessing infrastructure security, providing treatment technologies, and on supporting international cooperative water management. These areas of concern are addressed through a variety of programs that aim to ensure the continuation of an abundant, economical water supply.

Cliff Howard examines bolts and steel netting like that installed on many of the walls at the Waste Isolation Pilot Plant in southern New Mexico.

A Sandia technology, specific anion nanoengineered sorbents (SANS), has arsenic-trapping properties that may find application in city water systems. SANS is simpler, safer, and more efficient than purification technologies currently on the market. SANS may reduce the cost of municipal and rural communities' compliance with EPA standards and may also be economical enough for use in homes, schools, and apartment complexes served by single wells. SANS systems also can be adapted to rid industrial wastewater and process streams of other contaminants.

Towards Air Safety

Sandia's work toward a safer national air transportation system began in the early 1990s when, in a partnership with the Federal Aviation Administrtion (FAA), the labs began research on new technologies and systems approaches to assess the condition and safety of aircraft structures. First, our researchers focused on the aging aircraft of the nation's civilian air carriers, applying technology to better spot structural defects, and developing systems analyses to better communicate defects up the chain of command. The success of this effort led to a partnership with the Flight Standards Service of the FAA to incorporate our findings as one basis for the next-generation Air Transportation Oversight System.

Through a combination of computer modeling and experimentation, Dave Teter, left, and Pat Brady are among the Sandia developers of new materials they call specific anion nanoengineered sorbents (SANS). Water flowing through a column of the SANS would have its arsenic content reduced to undetectable levels.

Partnering *for a Strong* America

Sandia works in partnership with industry and universities to enhance the security, prosperity, and well-being of the nation. Industry and university partnerships are key to our mission of providing cost-effective scientific and engineering solutions to meet national needs in nuclear weapons and related defense systems, energy security, and environmental integrity—and to address emerging national challenges for both government and industry. If Sandia is to continue to be at the forefront of science and technology, partnering with the "best in class" must be an essential strategy.

Collaborating with industry and university partners enables Sandia to:

- *maintain at world-class level the competencies critical to our mission of nuclear weapons stockpile stewardship*
- *apply new technologies and innovations to our programs in support of the Department of Energy (DOE), other federal agencies, and industrial partners*
- *promote the transfer of technologies to key suppliers for applications to DOE systems*
- *develop a visibility in the academic world through collaborative research programs aiding the recruitment of new personnel; and*
- *gain opportunities to commercialize new Sandia-developed technologies through startup companies.*

From top: decontamination foam; extreme ultraviolet lithography; modeling Goodyear tires.

Al Romig,
Vice President
Science & Technology and Partnerships

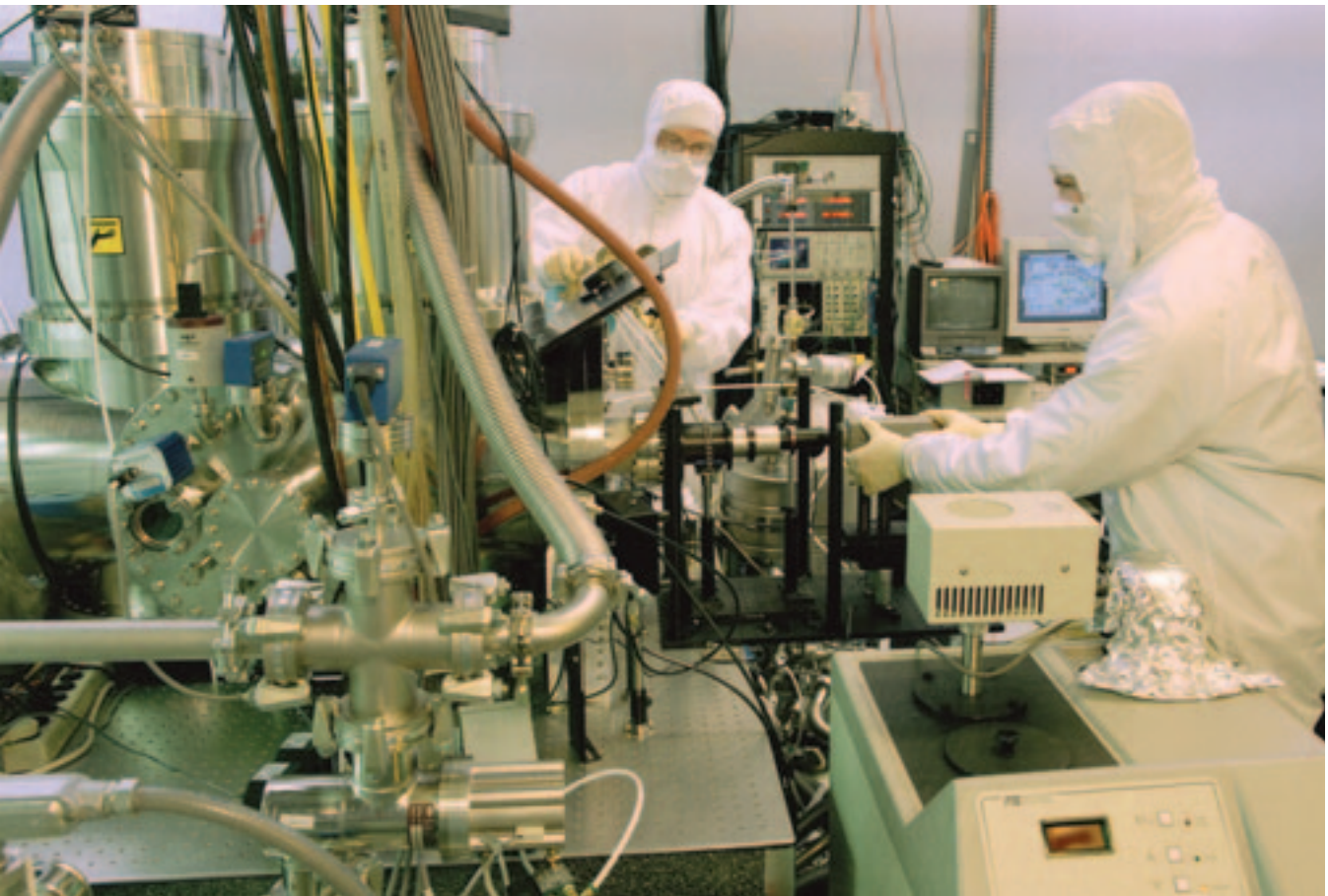
Among those attending the EUVL milestone celebration at Sandia's Livermore, Calif., site were, from left, Sandian Glenn Kubiak, California Rep. Ellen Tauscher, and John Gordon, administrator of the National Nuclear Security Administration.

CREATING NEW COMMERCIAL OPPORTUNITIES

(More details about many of the technologies mentioned in this section can be found in other sections of this publication.)

April 11, 2001, was a red-letter day in Sandia's long history of collaboration with the private sector. Some 250 members of industry, government, and three national laboratories celebrated a milestone in developing next-generation technology that eventually is expected to produce microprocessors that are 10 times more powerful than today's fastest chips, and memory chips that have 30 times more capacity. A prototype tool, known as the engineering test stand, had begun printing full-field images on 200mm wafers at Sandia's Livermore, Calif., site with extreme ultraviolet lithography (EUVL), whose narrow wavelengths enable ever-smaller features, allowing for more powerful chips.

Sandia, Lawrence Berkeley, and Lawrence Livermore national laboratories have worked with a consortium of semiconductor companies to achieve the technological breakthrough. The consortium has pledged up to $315 million to the project. The engineering test stand prototype will be used by consortium members and lithography tool suppliers over the next year to refine the technology and get it ready to create a prototype commercial machine that meets industry requirements for high-volume chip production. The next-generation lithography approach is now a leading contender for generations of commercial microchip production starting in 2005/6 through 2020. The consortium includes **Intel Corp.**, **Motorola**, **Advanced Micro Devices**, **Micron Technology**, **Infineon Technologies**, and **IBM Corp.**



Sandia researchers Jim Van De Vreugde, left, and Luis Bernardez, work in the extreme ultraviolet lithography laboratory.

Sandia computer scientist Sorin Istrail seeks inspiration from a 3-D lattice to help him visualize how chains of protein fold and misfold.

"The next stage of the biotechnology revolution that was started by the human genome program will be fueled by the successful marriage of molecular biology with high-performance computing science."

Former Energy Secretary Bill Richardson

"Our intent with this alliance is to apply the same full-system modeling approach to bio-science that has been so successfully applied to physical sciences in the DOE/NNSA Stockpile Stewardship program."

Bill Blake,
Vice President of High Performance Technical Computing, Compaq

"Just three years ago, the computational needs of biology were thought to be minor and irrelevant to the computing industry. Today, biologists are setting the pace of development for the industry."

J. Craig Venter,
President and Chief Scientific Officer, Celera

Sandia and **Celera Genomics**, a human genetics research company, are collaborating to develop next-generation software and computer hardware solutions specifically designed for the demands of computational biology. Scientists have already taken initial steps toward applying knowledge about gene sequencing and expression to conquering diseases. However, researchers still need much greater computing capabilities to perform the mathematical operations required to understand the meaning and function of genes. This project will develop high-performance computing solutions that can meet that challenge. The Accelerated Strategic Computing Initiative (ASCI) of the National Nuclear Security Administration benefits from this project because the Celera investments will provide the engineering foundation necessary for the next generation of supercomputers in the 100 TeraOPS (100 trillion operations per second) to 1 PetaOPS range (1,000 trillion operations per second).

Getting a look at Sandia's Cold Spray™ research system are, left to right, Neville Whittle of the Alcoa Technical Center, Gregg Wagner of Siemens/Westinghouse Power Corp., and Jeff Smith of the Howmet Corp. Sandia researcher Mark Smith, far right, shows them metal strips deposited by the system.

Also in the biomedical area, Sandia is collaborating with the **University of New Mexico Cancer Center** to develop computing technologies that may reveal the genetic basis of leukemia, a form of cancer that is now known to have many cellular variations. Funded by a $1 million grant from **The Keck Foundation**, the project team is building a microarray scanner that will be capable of making 10–20 simultaneous comparisons of tens of thousands of genes—a staggering increase in throughput, accuracy, and information over the current, slow procedure of one-to-one cell comparisons. Armed with the new tool, biomedical

Clint Atwood

Technology Transfer as a Contact Sport

In his advancement from manufacturing line machinist to driving force in the rapid prototyping community, and then the leap from technologist to business developer, Clint Atwood has always set and achieved ambitious goals.

As project manager for Sandia's Laser-Engineered Net Shaping multipartner cooperative research program, Atwood experimented with new techniques for building structures layer upon layer using laser deposition. R&D challenges included initial problems with dimensional precision and the rough texture of the metal's surface. He pioneered processes that solved both problems. Colleagues noticed his tenacity, outstanding organizational capabilities, and knack for guiding team members without smothering them.

Months after Atwood's move to a new office, file-filled boxes still sat under his work table. In his new role as business developer, he is engrossed in working the frontline of technology transfer. Effective communication lies at the heart of his partnership-development philosophy, and he encourages his technical staff to stay in close touch with industry counterparts. "I consider technology transfer to be a contact sport," he says. "The more active the role Sandia takes with industry partners, the more productive and rewarding the partnership is likely to be."

Atwood specializes in multicompany cooperative research and development agreements, which he describes as tremendously challenging because there are more people to keep happy and more things to juggle. Although making a technology palatable to a dozen different entities entails a certain amount of risk, it also offers multiple opportunities for success. And the pay-off—a stronger national economy—is crucial to continued competitiveness in the global marketplace. "Technology drives our economy, and integrating advanced technologies into commercial applications is one of the keys to a strong nation," he says.

researchers will be better able to understand the cellular changes produced by leukemia. The microscanner may lead to improved disease treatment and could help in developing a cure for cancer. This project affords Sandia an opportunity to extend expertise developed in nonbiological areas (optical instrumentation, hyperspectral imaging, and data visualization, for example) into biological areas, thereby advancing Sandia's long-term strategy for reducing the nation's vulnerability to biological attack.

Understanding how tires age has been a goal of an ongoing research partnership between Sandia and Goodyear Tire and Rubber Company. Sandia researcher Ken Gillen, front right, discusses a tire sample with Roger Assink, seated, Mike Malone, back left, and Gary Jones, back right.

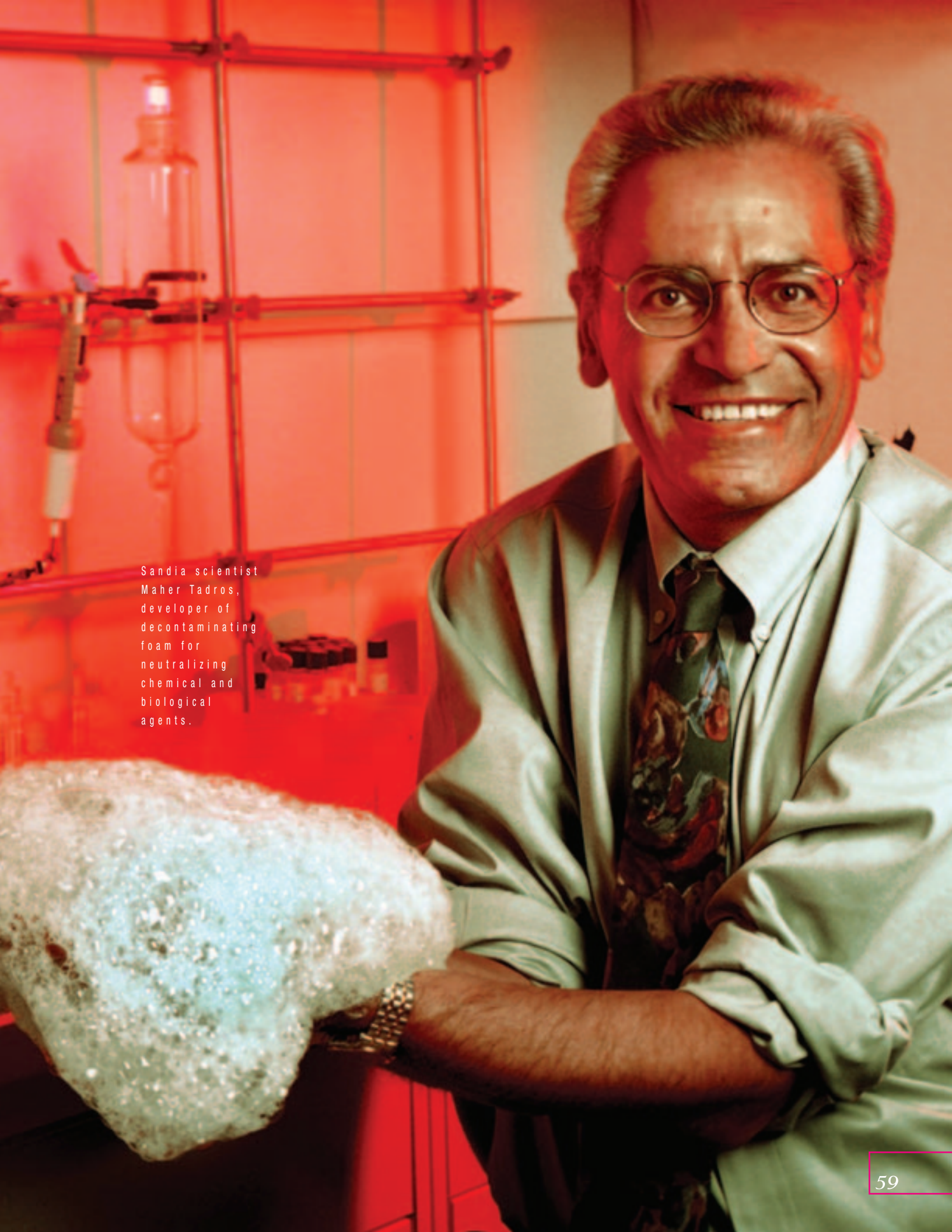
Sandia is working with 10 industry partners to accelerate the development and commercialization of the emerging, near-room-temperature, metal coating technology known as Cold Spray™. In the Cold Spray™ process, metal or composite powders are accelerated to hypersonic velocities in a compressed gas jet, and bond to a target surface by a process similar to explosive welding—but on a microscale. Cold Spray™ processes show unique promise for creating wear-resistant coating, fabricating durable small piece parts layer by layer, and joining chemically dissimilar materials with bonds that gradually transition from one material composition to another.

Consortium members want to use new Cold Spray™ processes to create wear-resistant coatings on car- or aircraft-engine components, for instance, or to deposit layers of reactive metals such as aluminum or copper onto substrates for use as heat-tolerant circuits. For weapons applications, Sandia might use them to create vacuum-tight seals in metals or high-quality metal-to-ceramic bonds without heat treatment, and perhaps as a low-temperature alternative to welding. Industry partners are **Alcoa**, **ASB Industries**, **DaimlerChrysler**, **Ford Motor Company**, **The Jacobs Chuck Manufacturing Company**, **Johnson Manufacturing**, and **Ktech**.

Sandia's foam for the rapid decontamination of chemical and biological warfare agents is being brought to market by **Modec** (Denver, Colo.), a specialist in mass-casualty response systems for weapons of mass destruction, and by **EnviroFoam Technologies** (Huntsville, Ala.). Each company acquired nonexclusive rights to manufacture and sell products based on Sandia's formulation in all fields of use. The foam neutralizes both chemical and biological agents and can begin decontaminating a disaster scene even before a specific contaminant has been identified. Unlike currently available decontaminating products, all of which are based on bleach, chlorinated solvents, or other hazardous or corrosive materials, Sandia's foam is made from safe household substances. It can be deployed as a foam, mist, fog, spray, or wipe. The formulation was shown to be effective in several tests with live agents in various laboratories and by the U.S. military at Aberdeen and Dugway proving grounds.

Sandia and **Goodyear Chemical**, a division of The Goodyear Tire & Rubber Company, are collaborating to explore new and more energy-efficient processes that may reduce energy consumption, waste generation, and environmental emissions. Goodyear research and development will provide engineering and economic modeling studies based on the company's Beaumont, Texas, solution polymer plant, which uses petrochemicals to produce synthetic rubber and specialty polymers. Sandia will use

> "CRADAs (cooperative research and development agreements) nurture cooperation between government labs and private U.S. businesses. Collaboration on emerging technologies can produce results that benefit our laboratories and raise manufacturing standards for U.S. industries as we address national concerns such as energy consumption."
>
> *Al Romig*
> *Sandia Vice President*
> *Science & Technology and Partnerships*



Sandia scientist Maher Tadros, developer of decontaminating foam for neutralizing chemical and biological agents.

advanced computer-aided design and engineering to test fabricated material recovery devices and quantify results. The agreement is the sixth CRADA between Goodyear and Sandia since 1993—and the first for the company's chemical business.

Sandia and the **University of New Mexico** have developed nanoscopic structures—structures in the microscopic 1–100-nanometer range—that self-assemble with functionality and are easily and inexpensively produced from inkjet printers and lithographic pens. The process links computer-aided design and inkjet printing to create functional nanostructures in just moments. It eliminates the need for lithography's tedious, sequential deposition of individual organic and inorganic layers, and brings a step closer to obsolescence the molds, masks, and photo resists common to most lithographic processes.

Interest continues to grow for Sandia's surface micromachining technology (Sandia ultraplanar multilevel MEMS technology, or SUMMiT) that produces MEMS (MicroElectroMechanical Systems) devices. **MEMX Inc.**, a spinoff company from Sandia's MicroElectroMechanical systems development activity, will commercialize a MEMS-based optical switch for the telecommunications industry. The license grants Sandia equity in the company

Sandia researchers, from left, Paul McWhorter, Sam Miller, Jeff Sniegowski, and Steve Rogers, have joined a private spinoff company, MEMX, Inc., to commercialize Sandia-developed microsystems technology.

in exchange for rights to develop business based on Sandia's intellectual property. This equity license offers an opportunity to share in the company's technical developments and financial successes while enabling Sandia to better meet its national security missions by developing a regional supplier base for MEMS devices.

Sandia is a world leader in the development of MicroElectroMechanical Systems (MEMS).

Ardesta, an Ann Arbor, Michigan-based company dedicated to the development of the microsystems industry, entered a partnership agreement with Sandia to transfer MEMS systems and microsystems technologies to startup companies in the commercial sector. Through this agreement, Ardesta secures a license to make and sell products using Sandia's SUMMiT technology, opening the door to future collaborative work between Sandia, Ardesta, and companies that Ardesta may form to commercialize MEMS and microsystems. Ardesta will also develop a design and training center in Albuquerque based on Sandia's SAMPLES™ (Sandia agile MEMS prototyping, layout tools, education, and services) prototyping model, which serves as a supporting infrastructure to the SUMMiT process.

Microcosm Technologies also signed a license agreement for Sandia's MEMS design tools. Microcosm will incorporate Sandia's MEMS applications and computer-aided design tools into the company's software tool kit. Sandia benefits from this new license by receiving royalties on products and services offered by Microcosm and also by having the required design, test, and layout software for Sandia's SAMPLES™ program in the hands of many more potential users.

Waters Corporation of Milford, Mass., a worldwide developer of analytical technologies, licensed Sandia's microfluidics technology and launched a cooperative research and development agreement to further develop this expertise. The company envisions coupling miniaturized chromatography systems with its mass spectrometry analytical products. This project is a major step forward in Sandia's vision to provide portable, miniature chemical-analysis systems for national security needs ranging from the detection of chemical and biological agents to the cleanup and monitoring of environmental waste sites.

The New Mexico State Legislature approved legislation that allows Sandia to earn a tax credit of up to $1.8 million a year in return for assisting small businesses in the state. Through its **New Mexico Small Business Assistance Program**, Sandia is providing consulting support to small businesses to help them resolve technological problems

Sandia researcher Diane Hurtado inspects some conventional artificial legs from the collection of the Seattle Orthopedic Group, part of a team that is developing an intelligent prosthetic lower limb at Sandia.

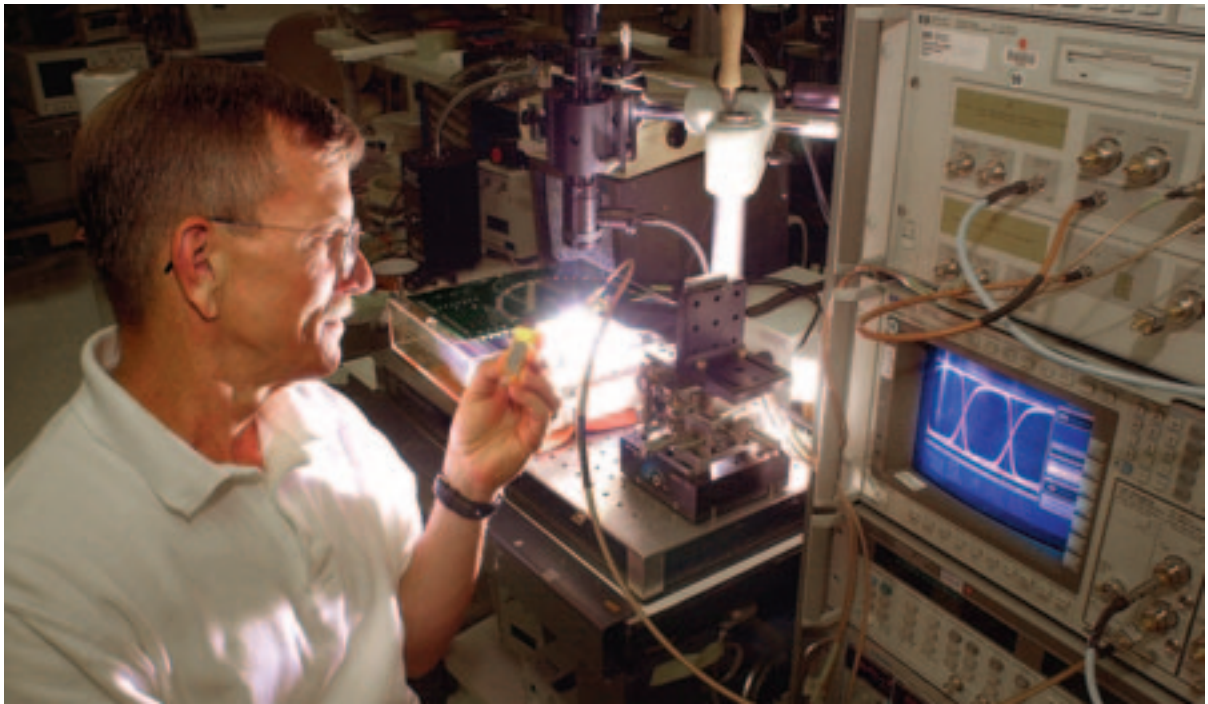
or business issues. The program's emphasis is on helping small businesses in rural areas of New Mexico. Sandia strove to complete 200 business assistance projects under the program this past year.

Funded by the Department of Energy and the New Mexico State Legislature, Sandia has completed a master development plan for the 217-acre **Science & Technology Park**, located next to Kirtland Air Force Base in Albuquerque, where Sandia is headquartered. The park's fiber optics backbone will become a part of the infrastructure in 2002 under a $1 million grant from the U.S. Economic Development Administration.

As of March 2001, the park had nine tenants employing 376 people. The anchor tenant, semiconductor manufacturer **EMCORE**, has added 36,000 square feet to its initial 50,000 square-foot facility, and now houses its Optical Devices and Solar Cells divisions in the park. EMCORE focuses on the design and manufacture of compound semiconductor products including solar cells and vertical-cavity surface-emitting lasers used in the communications industry.

New park tenants include **Team Specialty Products**, a strategic supplier to Sandia and supplier of sophisticated electromechanical devices to the pulsed power area of Sandia; **Training Solutions**, a branch of Analytical Solutions that develops products for the electronics industry; and **PicoDyne**, a semiconductor company specializing in new ultra-low-power technologies.

Park goals for the coming year include construction of a multi-tenant building to accommodate some of the smaller technology companies now working with Sandia.



Sandia researcher Dave Peterson takes a close-up view of a high-speed optical transceiver module, which about 50 Sandians helped to develop for EMCORE Corp.

Strengthening Our Communities

From top: Livermore Mayor Cathie Brown and Sandian Tim Sage prepare Sandia's 50th anniversary time capsule for burial; Albuquerque skyline; Dave Robinson with daughter at Family Science Night; Sandia's Shoes for Kids program.

A Commitment to Our Communities

We at Sandia take pride in being part of our communities. We cherish the beautiful areas in which we live as well as the wonderful people, our neighbors and friends. The people of Sandia National Laboratories have a long tradition of service in their communities. Since 1993, with support and encouragement from Lockheed Martin Corporation, our service and partnerships in the community have increased dramatically. We benefit tremendously from our partners and friends in our communities, and believe we are able to give back through our commitment and service.

Joan Woodard,
Executive Vice President and Deputy Director

STRENGTHENING OUR COMMUNITIES

A community's strength is often measured by how closely its people hold a shared vision. A community's wholeness and health arises, says humanitarian Millard Fuller, founder and president of Habitat for Humanity International, through people's love and concern for each other. Sandia as a corporation, as well as Sandians as individuals, are known for their commitment to building the health of their communities through contributions of personal time and resources. This tradition is strongly supported by Lockheed Martin Corporation, which manages Sandia for the Department of Energy's National Nuclear Security Administration.

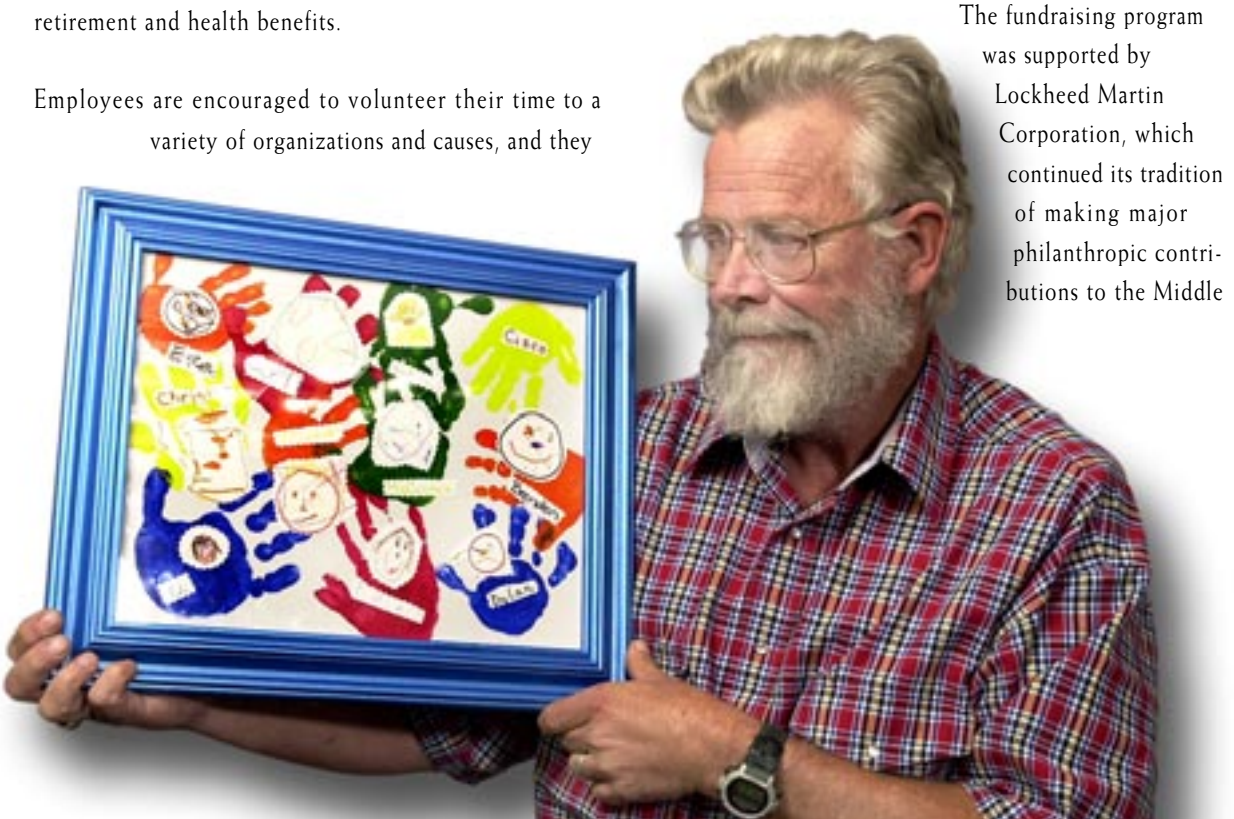
Sandia's community involvement focuses on growth strategies, workforce development, transportation issues, leadership programs, and business development. Sandia provides major economic benefits locally, regionally, and nationally through the approximately 7,500 employees, who generate a payroll of more than $704 million in direct salaries and contract labor. In 2000, Sandia's expenditures totaled more than $1.5 billion. We placed contracts with the private sector for $411 million in goods and services, including $206 million in contracts with New Mexico businesses and $47 million with California businesses. In New Mexico alone, Sandia generated $46 million in gross receipts taxes as well as other state revenues, and paid $147 million dollars in retirement and health benefits.

Employees are encouraged to volunteer their time to a variety of organizations and causes, and they respond enthusiastically by becoming role models and partners in community programs and contributing to youth education. This past year, Sandians volunteered 93,000 hours to helping others in New Mexico and California. The following are a few of the ways Sandians made a difference in their communities.

Two happy boys try out their new shoes provided through Sandia's Shoes for Kids program.

GIVING

- Sandians contributed more than $2 million to the annual Employee Contribution Plan for **United Way of Central New Mexico** for the second consecutive year. The fundraising program was supported by Lockheed Martin Corporation, which continued its tradition of making major philanthropic contributions to the Middle



Sandia manager Lee Cunningham with his most treasured piece of art—a "thank you" note from students at the Presbyterian Ear Institute for his volunteer work in building and decorating shelves and cubbies for them.

Rio Grande community, particularly in support of educational programs for youth.

- Sandians in California, through the **Livermore Employee Assistance Program,** donated more than $215,000 to charitable organizations. The annual charity drive has raised more than $3.4 million since 1969.

Belen High School student Tina McQuerry and her mentor, counselor Teresa Garde, speak at the Sandia Thunderbird Awards luncheon.

- One of Sandia's oldest traditions of community giving, our **Shoes for Kids** program, provided shoes for 450 children from 18 Albuquerque-area elementary schools last year. Shoes for Kids is funded by employee donations and has been helping needy children since 1959.

- Last year, Sandia and Lockheed Martin Corporation recognized 30 graduating high school students who excelled in school and community activities after overcoming adversities such as illness or addictions, surviving the deaths of parents, becoming teen parents, or living on their own. The annual **Thunderbird Awards** for exceptional achievement include a $1,200 grant.

- Thirty-five Sandians participated in **Christmas in April**, a national volunteer organization, by helping to paint a house that the New Mexico Homebuilders Association was refurbishing for an elderly woman with a dependent mentally handicapped son. Another eight Sandians spent 32 hours during the **Week of Caring** assisting local agencies in California.

- Sandia volunteers teamed with the Office Professional Quality Council in a drive to provide disposable diapers for the **New Futures High School**, an Albuquerque alternative school for teenage mothers and their babies.

- Sandia California's Administrative Professionals' Council teamed with **Family Crisis Services of Livermore** and the **San Joaquin County Food Bank** to gather donations for children.

Sandian Ron Stoltz of Sandia California helps children with their science experiment at the Department of Energy Day in Oakland, Calif.

Sandian Virginia Garcia came up with the idea of building a semitrailer out of food donations during the "Let's Fill a Semi" Roadrunner Food Drive.

- Sandians donated more than 35,000 pounds of food to Albuquerque's **Roadrunner Food Bank.** In addition, 14 Sandia volunteers helped to raise $8,600 for the bank by taking turns at Albuquerque's annual Balloon Fiesta as grill cooks. In California, 15 Sandians collected gifts of food, toys, and clothing for needy families during the **Holiday Spirit** campaign.

- More than 200 Sandia employees, family members, and retirees participated in **Make a Difference Day**, a national day of volunteering, doing such things as improving hiking trails, packing holiday food boxes, and painting, building shelves, and landscaping for local charitable organizations.

- Sandians donated children's books and raised money for new books at Marylin Avenue Elementary School in Livermore.

YOUTH EDUCATION

Our commitment to education focuses on educational outreach programs that help set the stage for scholastic success. This past year, Sandians supported these goals by judging science fairs, speaking at career events, helping to teach in the classroom, and serving as mentors and tutors.

- Sandia's **Environmental Education Program** provides students and teachers with hands-on activities that demonstrate the need to protect our natural resources. Sandians made presentations at a number of New Mexico events, including the fourth annual Youth Conference on the Environment, the Women in Science and Engineering Conference, and at the University of New Mexico's Valencia Campus Technology Fair.

- Sandia continued its long-standing support of a New Mexico state initiative, **Strengthening Quality in Schools**, which provides the expertise needed to

Sandia physicist John Reno takes his love for mathematics into the classroom, where he teaches a once-a-week, after-school math program for middle school students.

Carla Garcia Estrada, left, gives Allison Kong a pointer at the start of the Sandia Women Committee's Math and Science awards banquet in Livermore. The two juniors at Dublin High School were among 20 girls from area schools honored at the 10th annual event.

develop a world-class educational system in New Mexico. The lab established the **Excellence in Science Teaching Award**, and the first recipients were 11 outstanding teachers who had influenced the quality of science instruction by inspiring student interest and enthusiasm in science.

- Sandia's **CroSSlinks** program brought together 30 Sandia volunteers to serve as technical role models in 40 local elementary schools. The series included **Family Science Night** programs, in which school children and their parents enjoyed an evening of educational hands-on science activities.

- The National Atomic Museum, a science and history museum operated by Sandia for the DOE on Kirtland Air Force Base in Albuquerque, launched a mobile **Science and Math Outreach** program. The program is designed to bring information about science and technology into many of New Mexico's small towns and pueblos. Nearly 20,000 schoolchildren participated in the museum's educational programs over the past year, including the **Science is Everywhere Summer Camp** that offered preteen children hands-on experience with robots, rockets, engineering, energy, and the environment. Lockheed Martin Corporation announced it was donating $1 million to the museum's education-outreach programs.

- Sixty-five Sandians volunteered as mentors and student escorts for the second annual **School to World** career day. The activity gave students an opportunity to talk with people in the working world about job opportunities and the relationship between schoolwork and work skills. Sandia and New Mexico businesses, schools, and government agencies sponsored the event.

Sixth-grader Katie Dunn has an electrifying experience during Space Day 2001. Lockheed Martin Corporation hosted 85 students for the annual celebration, which included briefings, presentations, and hands-on learning.

Leonard Duda

Volunteer Extraordinaire

Realizing that books alone are a dull way to teach science, Sandian Leonard Duda uses hands-on learning to make elementary physics and chemistry come alive for grade-school children.

In the 10-plus years he has volunteered in New Mexico classrooms as part of Sandia's Science Advisor Program and now the CroSSlinks program, Duda has found that "the messier the experiment, the more fun the kids have." So he has students release clouds of soap bubbles to demonstrate the lift created by the Bernoulli effect—the principle of winged flight. And he graphically portrays the dynamics that exist between friction and gravity by filling a paper cup with water and rigging it to be slowly pulled by gravity to the edge of a wooden block, where it plunges to the floor in the experiment's grand finale.

Duda focuses his volunteer activities on education not only because he believes in the importance of science instruction, but also because he thinks children can benefit from becoming more aware of scientists, most of whom lack the high public profile typical of movie stars and athletes.

"Having someone other than the classroom teacher involved in science education helps the kids get a feeling for the subject from a scientist's viewpoint," he says.

In 1999, Duda also became a NASA Jet Propulsion Laboratory Solar System ambassador, a position that takes him into the community for presentations on the Galileo spacecraft and other planetary reconnaissance programs.

Of all his volunteer activities, the most demanding was his recent role as interim director of Albuquerque's Explora Science Center and Children's Museum, a 10,000-square-foot facility staffed with 11 full-time employees. As president-elect of the museum's board of directors, Duda had the knowledge needed to fill the void created by a transition in the museum's directorship.

"My Sandia manager was confident I could both serve as the museum's interim director and accomplish my workload at Sandia," he says.

Duda, whose early scientific training was in physical chemistry, is responsible at Sandia for calibrating instruments in Sandia's Primary Standards Laboratory, the standards-setter for other DOE labs. So, every week for six months his typical workday started with a 6 a.m. arrival at Sandia, where he would respond to e-mail, make telephone calls, and go into his laboratory to make calibration measurements until late morning.

He then drove to the museum and for the next seven hours focused on staff matters, worked with exhibit designers, interacted with City of Albuquerque officials and architects, and oversaw the new-exhibit delivery schedule. At 6:30 p.m., Duda shifted into his role as community science presenter. Around 9:30 p.m., he finally headed home to rest up before doing it all over again the next day.

High school senior Ryan Cook learns from Sandian Rusty Escapule during a job shadow day.

- More than 80 Sandians in California spent more than 700 hours organizing a Saturday **Expanding Your Horizons in Math and Science** program that intoduced almost 1,000 young women to technical fields. The event included daylong conferences in San Ramon and Stockton.

- In 2000, Sandia **internships** brought 700 students to Albuquerque and more than 200 to Livermore for mentoring and immersion in our culture and work. Half of these students were interns in our **summer employment program**. An additional 12 interns in Albuquerque were drawn from graduates of our **Advanced Manufacturing Academy**, which gives students at Albuquerque high schools information about employment in technical fields. The academy's elective four-year curriculum stresses math, physics, chemistry, computer applications and computer-aided design, machining and materials processing skills, and automotive and transportation technologies.

- Our **Hands-On/Minds-On** programs instruct about 400 middle and high school students each year in robotics and bridges, math and money, Web page design, and health and medicine. The programs are designed to give Native American, African American, and Hispanic students hands-on science and engineering experiences.

- Sandia volunteers again supported the regional **Science Bowl**, an academic competition for teams from area high schools. The winning team from Mission San Jose High School in Fremont, Calif., competed nationally at the DOE's runoff in Washington, D.C., where DOE Secretary Spencer Abraham honored Sandians for 10 consecutive years of volunteer support.

- Sandian Nina Berry has fostered the careers of scores of students in the **College Cyber Defender's Program**. Sandia has hired some of the students. Berry received a national Women of Color Award for her work as a mentor.

CHALLENGING ISSUES

Sandia helps numerous New Mexico businesses and civic organizations address community needs such as water and air quality, arid land issues, safety, and security. Our expertise in countering threats is an example of how Sandia shares information, technology, and new techniques that can improve the overall quality of life. Sandia holds bomb-squad seminars nationwide and has developed a partnership with the New Mexico National Guard for training first responders to a crisis situation—a program that may become a nationwide model.

Sandia Annual Report 2001 staff:

Editor: Chris Miller, Sandia National Laboratories
Design/Layout: Michael Vittitow, Sandia National Laboratories
Writing: Peter Nolan, Technology Marketing
Ryan DeMares, Technically Write
Nancy Garcia, Sandia National Laboratories
Photography: Randy J. Montoya, Sandia National Laboratories, NM
Lynda Hadley, Sandia National Laboratories, CA
Bill Doty, Bill Doty Photoimaging
A special thanks to the many Sandians who provided suggestions, support, and information for this publication.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.
SAND2001-2782P. CA.MV.10.01